

**" A DC-AC Converter for Igniting and
Supplying a Gas Discharge Lamp "**

This invention relates to a DC-AC converter for igniting and supplying a gas discharge lamp, e.g. a fluorescent lamp, the converter having two input terminals intended to be connected to a d.c. voltage source, the input terminals being connected together in series by an arrangement of at least a first semiconductor switching element, a capacitor and a load circuit comprising at least an induction coil and the gas discharge lamp. The capacitor and load circuit are shunted by a second semiconductor switching element provided with a control circuit comprising at least a starter circuit and a resonant circuit. The resonant circuit includes the parallel arrangement of the transformer primary winding and a capacitor in one branch and the gas discharge lamp in the other branch.

A DC-AC converter of this type is known from US-A- 4,415,838 and US-A- 4,748,383. The undimmed lamp situation is concerned in this case. In this known converter a transformer is present in the load circuit (in which the lamp is incorporated). This transformer has two secondary windings which form part of the control circuits of the semiconductor switching elements. The switching elements are rendered alternatively conducting and non-conducting by means of the transformer and the control circuits respectively. This known converter is designed for an electrodeless low-pressure gas discharge lamp.

However, a drawback of the known circuit is that in order to start a gas discharge lamp, e.g. a fluorescent lamp, a much higher voltage needs to be supplied to the lamp and hence the voltage across the resonant circuit which is incorporated in the series arrangement is much higher than the operating voltage. This results in a potential risk to the semiconductor switching elements. It has also been found that when the above mentioned arrangement is used for running multiple lamps with the same DC-AC converter a high current through one induction coil which is incorporated in the series arrangement with the resonant circuit and the lamps is needed to be able to supply enough power for the lamps. This is a drawback because such circuits cannot easily be used universally with lamps having different power ratings. The known circuit doesn't allow the current supplied to the lamp to be set to a predetermined value during operation of the lamp, this would offer a longer lamp life because the current through the lamp increases due to ageing, or in the case of a low pressure vapour discharge lamp, operation at a relatively hot location.

It is an object of the invention to overcome the above-mentioned problems by providing an arrangement of the type described in the opening paragraph in which the voltage across the parallel resonant circuit in the control circuit during igniting and operation is always substantially constant, and by providing a circuit which can be universally used for multiple lamps with different power ratings or for lamps whose arc current varies with age.

Accordingly, the present invention provides a DC-AC converter for igniting and supplying a gas discharge lamp, comprising: first and second input terminals for connection

to a source of DC voltage; first and second semiconductor switching elements each having a source electrode, a drain electrode and a control electrode, the first and second semiconductor switching elements being connected in a first series circuit across said first and second input terminals; a capacitive voltage divider having first and second capacitors, one end of said capacitive voltage divider being connected to a junction point between said first and second semiconductor switching elements and the other end of said capacitive voltage divider being connected to said second input terminal; a transformer having a primary winding, a first secondary winding and a second secondary winding, said primary winding being connected in a parallel circuit with said second capacitor via a first resistor, said first secondary winding and said ^{second} secondary winding being arranged to apply respective switching voltages to the control electrodes of said first and second semiconductor switching elements to render said first and second semiconductor elements alternately conducting in response to a current in the primary winding; a load circuit having one end connected to the junction point between said first and second semiconductor switching elements and the other end connected to said second input terminal via a current sensor resistor, said load circuit comprising a third capacitor, an induction coil and a gas discharge lamp connected in series, one end of said current sensor resistor being connected to a first resistive voltage divider via a fourth resistor, said first resistive voltage divider comprising a second resistor and a third resistor; a first diode and a third semiconductor switching element connected across said primary winding, a base electrode of said third semiconductor switching element being connected to the junction point of said first resistive voltage divider; a second resistive voltage divider connected across said lamp, said second resistive

voltage divider comprising a fifth resistor and a sixth resistor; and a fourth semiconductor switching element having a collector electrode connected to one end of said first resistive divider via a second diode and an emitter electrode connected to the other end of said first resistive voltage divider, a base electrode of said fourth switching element being connected to a junction point of said second resistive voltage divider via a third diode of a voltage rectifier which comprises said third diode and a fourth capacitor.

Thus, a DC-AC converter embodying the invention for igniting and supplying a gas discharge lamp comprises: a converter control circuit including a starter circuit containing first and second switching elements and a third switching element; a load circuit including at least one gas discharge lamp; and an igniting circuit including a fourth switching element; wherein the converter control circuit controls a current through the lamp via a current sensor resistor during a pre-heating stage, the igniting circuit disables the third switching element and thereby isolates the converter control circuit during an igniting stage and the converter control circuit controls the current through the lamp via the current sensor resistor during normal operation.

The control circuit of a converter embodying the present invention bypasses the high voltage peak away from the parallel resonant circuit whilst igniting the lamp thereby eliminating any risk of damaging the switching elements. The first capacitor is coupled to the resonant second capacitor to form the capacitive voltage divider whereby the voltage across the resonant circuit can be set by selecting the capacitor value. The capacitances of the voltage divider are chosen so that their impedances at the

operating frequency of the converter are high. Preferably a value is chosen for the voltage divider at which the power dissipation in the control circuit during operation is negligible. Whilst igniting the lamp no interference signals are generated on the switching elements. The energy dissipation in the control circuit is also greatly reduced during igniting.

An embodiment of the present invention can be universally used with multiple lamps of different power ratings by connecting an additional load circuit to the converter. Therefore, the circuit can provide an easy way of lighting multiple lamps of different power ratings by one DC-AC converter. Because an induction coil of low impedance can be used, the energy dissipation in the load circuit is also greatly reduced during operation. In addition, the entire circuit of the converter based on this simple circuit can easily be integrated into the lamp base of a compact gas discharge lamp.

In an embodiment of the present invention, the converter starting circuit comprises a resistor which is connected between the drain electrode and the control electrode of the first semiconductor switching element and a capacitor coupled between the control electrode and one end of the first secondary winding of the transformer as described in US-A-4,748,383.

According to an embodiment of the present invention, an igniting circuit comprising at least the second resistive voltage divider and the fourth semiconductor switching element is coupled to a control electrode of a third semiconductor switching element via the first resistive voltage divider. Whilst igniting the lamp a sufficiently high voltage is present across the

second resistive voltage divider to allow the fourth semiconductor switching element, coupled to the second resistive voltage divider through the third diode to become conductive so as to disable the third semiconductor switching element. As a result enough current at a relatively low frequency flows through the lamp so that the lamp can be ignited. When the lamp is ignited, the voltage across the lamp is reduced to a normal operation voltage, and the fourth semiconductor switching element becomes non-conductive so as to enable the third semiconductor switching element of the control circuit. The control circuit is now operative.

An embodiment of the present invention is based on the recognition that upon switching on the converter the capacitor arranged between the control electrode of the first switching element and the first secondary winding of the transformer is first charged until the voltage on the control electrode is sufficiently high to render the switching element conducting. As a result a current flows to charge up the capacitor in the load circuit and the capacitive voltage divider. The parallel resonant circuit including the second capacitor of the voltage divider and the primary winding of the transformer then starts oscillating due to the current through the capacitive voltage divider. The primary winding of the transformer incorporated in the resonant circuit then takes over the driving of the semiconductor switching elements via the two secondary windings of the transformer which are connected to the control electrodes of the switching elements. The switching elements are then rendered alternately conducting and non-conducting at the resonant frequency of the parallel resonant circuit thereby supplying the high frequency power signals for the gas discharge lamp. Meanwhile, the capacitor of the rectifier arranged between

the base electrode and the emitter electrode of the fourth semiconductor switching element is now charged until the voltage on the base electrode is sufficiently high to render the fourth switching element conducting to ignite the gas discharge lamp. The third switching element is disabled during the igniting. When the lamp is ignited, the fourth switching element becomes non-conductive due to the operating voltage of the lamp and the third switching element is enabled to activate the control circuit. The sensor resistor for measuring the current through the lamp is coupled to the third semiconductor switching element which is connected across the primary winding of the transformer in the resonant circuit to control the period of the conductance duty cycle of the first switching element on the converter. When the current through the sensor resistor reaches a threshold, the third switching element conducts, thereby reducing the conductance duty cycle of the first switching element on the converter. As a result the current through the lamp can be set to a predetermined value during operation.

The invention is particularly advantageous for use in low-pressure mercury vapour discharge lamps in which the operating current varies due to the discharge tube ageing. During operation of fluorescent lamps, an increase in the current through the lamp occurs due to a decrease of the impedance of the lamp as the lamp ages. As a result this causes the life of the fluorescent lamp to be reduced. An embodiment of the present invention makes it possible to maintain the lamp current at a constant value over the life of the lamp which can offer an extension of the lamp life.

In order that the invention may be more readily understood, and so that further features thereof may be appreciated, an embodiment of the present invention will

now be described with reference to the accompanying drawing which illustrates diagrammatically an embodiment of the converter according to the present invention.

The supply circuit in the drawing has two input terminals 1 and 2 intended to be connected to an alternating voltage source of 220-240V, 50Hz. These terminals are connected via a fuse 3 to a full wave rectifier 4. The output voltage of this rectifier is smoothed by means of the capacitor 5. Furthermore, a mains interference suppression filter constituted by a high frequency capacitor 6 and coil 7 together with capacitor 5 is connected between the rectifier and the input terminals A and B of the DC-AC converter. The capacitor 8 of the supply circuit constitutes the DC voltage source for the DC-AC converter.

The converter will now be described. The terminals A and B are connected together by means of a series arrangement of a first semiconductor switching element 10 and a second semiconductor switching element 16. The switching elements are power MOS-FET type transistors.

The transistors 10 and 16 are connected together in such a manner that the source electrode of the transistor 10 is connected to the drain electrode of the transistor 16.

The second semiconductor switching element 16 is shunted by means of a series arrangement of a load circuit made up of a capacitor 39, an induction coil 40, the electrodes 41 and 43 of the lamp 42 (with capacitor 44) and a sensor resistor 37 in one branch, and a capacitive voltage divider (22,23) in the other branch.

The second capacitor 23 of the capacitive voltage divider (22,23) and a primary winding 27 of a current transformer 28 forms a parallel resonant circuit for the control circuit. A resistor 24 is coupled between the capacitor 23 and the primary winding 27 to optimise the phase of the drive signal for the switching elements 10 and 16. A third semiconductor switching element 26 in the control circuit is then bridged by the primary winding 27 via a coupling diode 25 which is used to protect the third switching element from any reverse current from the primary winding 27. The current sensor resistor 37 which is used to provide the feedback signal for the control circuit is coupled to the control electrode of the third switching element via a first resistive voltage divider 30 and 29 and a resistor 31. The current threshold value through the lamp can be set to the predetermined value by selecting the resistance ratio of the resistors 30 and 29 in the first resistive voltage divider. The third switching element 26 controls the positive cycle of the resonant waveform of the parallel resonant circuit.

The transformer 28 has two secondary windings 13 and 19. Winding 13 forms a part of the control circuit of the switching element 10 and is connected between the control electrode and the source electrode of the switching element 10. The ends of the winding 13 are connected to a voltage limiting circuit consisting of a series arrangement of two oppositely arranged Zener diodes 14 and 15 via a resistor 11 and a capacitor 12. Winding 19 forms a part of the control circuit of the switching element 16 and is bridged via the resistor 17 and the capacitor 18 by the series arrangement of oppositely arranged Zener diodes 20 and 21.

A starter circuit for the converter forms a part of the control circuit of the semiconductor switching element 10. The starter includes a resistor 9 which is connected between a drain electrode and the control electrode of the switching element 10, together with the capacitor 12 which is connected between the control electrode and one end of the secondary winding 13. This type of starter circuit is described in US-A-4,748,383.

The igniting circuit for the gas discharge lamp includes a second resistive voltage divider 38 and 36, a voltage rectifier 35 and 34 and a fourth semiconductor switching element 33. The second resistive voltage divider 38 and 36 is connected across the lamp to sense the voltage across the lamp. The fourth switching element 33 is bridged by the first resistive voltage divider 29 and 30 via a coupling diode 32 which is used to protect the fourth switching element 33 from any reverse current. The resistance ratio of the resistors 38 and 36 in the second resistive voltage divider is chosen to render the fourth switching element 33 conducting during igniting and non-conducting during normal operation.

The converter operates as follows. If the terminals 1 and 2 are connected to the AC supply mains (e.g. 220-240V, 50Hz), the capacitors 5, 6 and 8 will be rapidly charged via the rectifier 4 up to the peak value of the AC voltage source. This results in the DC voltage being present across the input terminals A and B of the DC-AC converter. Meanwhile the capacitors 12, 22, 23 and 39 are charged via resistor 9 until the voltage across capacitor 12 reaches a threshold at which the semiconductor switching element 10 becomes conductive. Then a higher current flows through the series arrangement of the capacitor 39 and the load circuit (40, 41, 44, 43) as

well as the current sensor resistor 37. The capacitor 23 in the parallel resonant circuit (23, 24, 27) is then quickly charged up via the first capacitor 22 of the capacitive voltage divider. An oscillation is then produced in this circuit whereafter the transformer 28 renders the semiconductor switching element 10 non-conducting and renders the semiconductor switching element 16 conducting. This produces a current through the capacitor 18 whereafter the switching element 16 becomes non-conducting again and the switching element 10 becomes conducting again and so forth.

During the igniting, the high voltage present across the lamp charges up capacitor 34 of the igniting circuit via the resistor 38. Meanwhile the current through the filament 41 and 43 of the lamp preheats the lamp and the third switching element 26 performs the control function via the current sensor resistor 37 to control the current through the lamp in a preheating stage. The current through the lamp can then be maintained to the predetermined value at a relatively high operational frequency due to the relatively short conductance duty cycle of the switching element 10. When the voltage across the capacitor 34 reaches the threshold value, the fourth switching element 33 becomes conductive and the control circuit is then disabled. Meanwhile the sufficiently high current and relatively low frequency power signal through the lamp ignites the lamp. After the lamp has ignited, the operating voltage present across the lamp renders the fourth switching element 33 non conducting and the control circuit enabled. This arrangement provides the soft starting property of the converter and provides the way in which the lamp can be preheated before igniting.

If during normal operation the current through the lamp exceeds the threshold value due to the ageing of the lamp, the third switching element 26 becomes conducting to render the switching element 10 non-conducting at an earlier stage. This arrangement provides a way of controlling the period of the conductance duty cycle of the switching element 10, and maintains a constant current through the lamp during the lamp life. This results in an extension of the lamp life.

In one embodiment of the present invention, the most important circuit elements have the values as shown in the Table below :

TABLE

capacitor 12	0.47	uF
capacitor 18	0.47	uF
capacitor 22	220	pF
capacitor 23	680	pF
capacitor 39	0.1	uF
capacitor 44	15	nF
capacitor 34	10	uF
coil 40	500	uH
resistor 9	10	MOhm
resistor 11	10	Ohm
resistor 17	10	Ohm
resistor 24	330	Ohm
resistor 29	10	KOhm
resistor 30	5.6	KOhm
resistor 31	220	Ohm
resistor 36	10	KOhm
resistor 37	0.75	Ohm
resistor 38	120	KOhm
zener diodes 14,20	12	Volts
zener diodes 15,21	7.5	Volts
transformer		
primary winding 27	6.30	mH
secondary windings 13, 19	670	uH

The gas discharge lamp (42) which is connected to the circuit specified in the above table is a fluorescent lamp having a power of 58.65 W. For a fluorescent lamp having

a power of 40 W, the inductance value of an induction coil 40 and the capacitance value of a capacitor 44 would be set to 700 μH and 12 nF, respectively, to meet the operating condition of the lamp. The current sensor resistor 37 would need to be set to 1.5 Ohm having an operating current of 0.15 A. If the DC-AC converter is used for dual lamps, the additional load circuit comprising a capacitor and an induction coil as well as the additional lamp can be connected into the circuit by means of connecting the additional load circuit between the drain electrode of the semiconductor switching element 16 and one terminal of the sensor resistor 37 together with the correct value of the sensor resistor 37. The DC-AC converter described above is suitable to use for multiple lamps with different range of power ratings.

**CLAIMS :-**

1. A DC-AC converter for igniting and supplying a gas discharge lamp, comprising: first and second input terminals for connection to a source of DC voltage; first and second semiconductor switching elements each having a source electrode, a drain electrode and a control electrode, the first and second semiconductor switching elements being connected in a first series circuit across said first and second input terminals; a capacitive voltage divider having first and second capacitors, one end of said capacitive voltage divider being connected to a junction point between said first and second semiconductor switching elements and the other end of said capacitive voltage divider being connected to said second input terminal; a transformer having a primary winding, a first secondary winding and a second secondary winding, said primary winding being connected in a parallel circuit with said second capacitor via a first resistor, said first secondary winding and said ^{second} secondary winding being arranged to apply respective switching voltages to the control electrodes of said first and second semiconductor switching elements to render said first and second semiconductor elements alternately conducting in response to a current in the primary winding; a load circuit having one end connected to the junction point between said first and second semiconductor switching elements and the other end connected to said second input terminal via a current sensor resistor, said load circuit comprising a third capacitor, an induction coil and a gas discharge lamp connected in series, one end of said current sensor resistor being connected to a first resistive voltage divider via a fourth resistor, said first resistive voltage divider comprising a second resistor and a third resistor; a first diode and a third semiconductor switching element



connected across said primary winding, a base electrode of said third semiconductor switching element being connected to the junction point of said first resistive voltage divider; a second resistive voltage divider connected across said lamp, said second resistive voltage divider comprising a fifth resistor and a sixth resistor; and a fourth semiconductor switching element having a collector electrode connected to one end of said first resistive divider via a second diode and an emitter electrode connected to the other end of said first resistive voltage divider, a base electrode of said fourth switching element being connected to a junction point of said second resistive voltage divider via a third diode of a voltage rectifier which comprises said third diode and a fourth capacitor.

2. A DC-AC converter according to claim 1, wherein the DC-AC converter further comprises : a seventh resistor connected between the drain electrode and the control electrode of said first semiconductor switching element; an eighth resistor and a fifth capacitor connected in series with said first secondary winding between the control electrode and the source electrode of said first semiconductor switching element, said seventh resistor and said fifth capacitor forming a starter circuit; a series arrangement of oppositely arranged first and second Zener diodes connected between the control electrode and the source electrode of said first semiconductor switching element to form a voltage-limiting circuit for said first semiconductor switching element; ~~means for connecting~~ a ninth resistor and a sixth capacitor connected in series with said second secondary winding between the control electrode and source electrode of said second semiconductor switching element; and a series arrangement of oppositely arranged third and fourth Zener diodes connected between



the control electrode and the source electrode of said second semiconductor switching element to form a voltage-limiting circuit for said second semiconductor switching element.

3. A DC-AC converter according to Claim 1 or 2, wherein said second resistive voltage divider and said fourth semiconductor ^{element} ~~means~~ form an igniting circuit used to disable and enable the third semiconductor switching element during the igniting and after the igniting, respectively.

4. A DC-AC converter according to any preceding claim, wherein said parallel circuit comprising said second capacitor in said capacitive voltage divider, said first resistor and said primary winding forms a high frequency parallel resonant circuit that produces a high frequency oscillation current in the transformer primary winding in the operating condition of the converter.

5. A DC-AC converter according to any preceding claim wherein the capacitance of the capacitive voltage divider is chosen so that its impedance is high at the converter operating frequency.

6. A DC-AC converter according to any preceding claim, wherein said current sensor resistor is coupled to the base electrode of said third semiconductor switching element via said fourth resistor and said second resistor of said first resistive voltage divider, the current through said load circuit controls the time of conductance of said third semiconductor switching element and a threshold voltage value for conductance of said third semiconductor switching element is set to a certain value by selecting the resistance of said current sensor



resistor, or the resistance ratio of the resistive voltage divider, whereby the period of the conductance duty cycle of said first semiconductor switching element, and hence the current through the lamp, can be controlled.

7. A DC-AC converter according to any preceding claim, wherein said third semiconductor switching element and said first diode are connected in series across said primary winding, whereby the positive cycle period of the resonant wave of said parallel resonant circuit can be adjusted, said first diode being used to protect said third switching element against reverse current.

8. A DC-AC converter according to any preceding claim, wherein a second series circuit across said first and second input terminals includes, in series, said first semiconductor switching element, said first capacitor and said parallel circuit.

9. A DC-AC converter according to Claim 8, wherein a third series circuit across said first and second input terminals includes, in series, said first semiconductor switching element, said load circuit and said current sensor resistor.

10. A DC-AC converter substantially as herein described with reference to the accompanying drawing.