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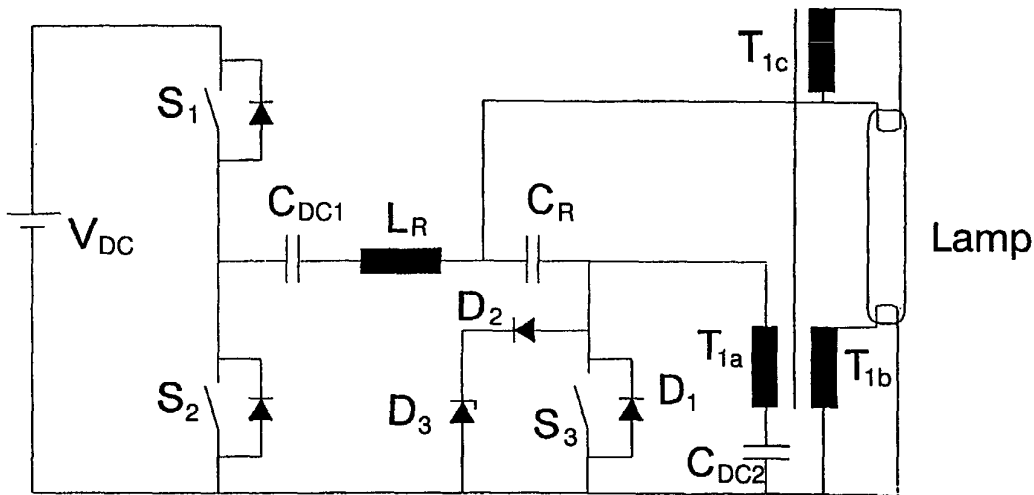
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Electronic ballast for fluorescent lamp

(57) The invention relates to an electronic ballast for a fluorescent lamp, the lamp load circuit being connected between the inverter power switch elements (S_1 , S_2). The lamp load circuit comprises an inductor (L_R) in a series connection with the lamp. Prior to the ignition of the lamp, the lamp load circuit also includes a capacitor (C_R) in a series connection with the heating transformer primary winding (T_{1a}), this series connection being in

parallel with the lamp. The heating current is supplied to the lamp cathodes solely via the heating transformer secondary windings (T_{1b} , T_{1c}), whereby the heating current can be shut off by way of setting a switch element (S_3) that is in parallel with the transformer primary winding (T_{1a}) in an ON condition. The heating current may be controlled to a desired level by driving the switch (S_3) ON and OFF with a pulse-width-controlled drive signal.



Schematic diagram of a heating circuit for the cathodes of a fluorescent lamp

Fig.1

Description

[0001] The present invention relates to an electronic ballast for a fluorescent lamp, the ballast comprising

- an inverter which is supplied from a DC voltage source and includes two power switch elements operating in a half-bridge totem-pole configuration for generating a high-frequency voltage,
- a lamp load circuit which is connected to the inverter and comprises an inductor and a capacitor that in a series connection form a series-resonant circuit and to which the fluorescent lamp can be connected, and
- a heating circuit of the fluorescent lamp cathodes, the heating circuit including a transformer having a primary winding connected in series with the capacitor of the resonant circuit and secondary windings connected in parallel with the cathodes of the fluorescent lamp,

whereby the fluorescent lamp is adapted connectable in parallel with the series connection of the capacitor of the resonant circuit and the transformer primary winding.

[0002] This kind of a ballast is known from patent publication EP 589 081 B1. This prior-art ballast provides the heating current to a first cathode of the lamp by means of connecting the cathode in series with the components of the resonant circuit. The heating current of the second cathode is generated by means of a secondary winding of the cathode current sense transformer. In the embodiment shown in FIG. 5, there is arranged a switch in parallel with the primary winding of a current sense/drive transformer so that different sensitivities can be selected for current sense. This prior-art ballast circuitry has no facility for cutting off the heating current of lamp cathodes either when the lamp strikes or just before the ignition of the lamp, but instead depending on the implementation of the circuitry, more or less cathode current remains to flow in one or both cathodes even after the lamp strikes. Another shortcoming is that the heating currents of the cathodes are out of balance with each other, whereby the sensing thereof as well as the cathode current control based on the sensed cathode current become complicated. Also the wear of cathodes is uneven.

[0003] It is an object of the invention to provide an improved ballast capable of driving the cathodes with a balanced and controllable heating current that can be switched off in a controlled manner.

[0004] The goal of the invention is achieved by way of the features specified in appended claim 1. Details of preferred embodiments of the invention are disclosed in the dependent claims.

[0005] In the following, the invention will be examined in greater detail with the help of an exemplary embodiment by making reference to the appended drawings in

which

FIG. 1 shows a circuit diagram elucidating an electronic ballast according to the invention as to its basic components;

FIG. 2 shows a plot of the voltage at the common point of the resonant circuit capacitor and inductor referenced to the ground potential of the supply voltage during the preheating cycle;

FIG. 3 shows a plot of the primary and secondary voltages of transformer T_1 for a low cathode resistance;

FIG. 4 shows a plot of the primary and secondary voltages of transformer T_1 for a high cathode resistance;

FIG. 5 shows the circuit diagram of FIG. 1 complemented with the sense and control signals of cathode heating circuit and a control block (A) suited for receiving, handling and transmitting signals, whereby the embodiment illustrated in FIG. 5 differs from that of FIG. 1 only therein that capacitor C_{DC2} has been moved to the other end of the primary winding T_{1a} of transformer T_1 ; and

FIG. 6 shows at two different power control levels the voltage over primary winding T_{1a} of transformer T_1 (upper diagrams) and the control signals of switch S_3 connected over the winding (lower diagrams).

[0006] In the configuration shown in FIG. 1, switches S_1 and S_2 form the normal half-bridge of a lamp circuit. Capacitor C_{DC1} blocks the DC component of the lamp drive voltage. Inductor L_R and capacitor C_R serve as the conventional resonant circuit used for striking the lamp. The lamp is stabilized to a desired intensity level by way of controlling the operating frequency of the half-bridge totem-pole connected switch transistors S_1 and S_2 .

[0007] The above-described conventional ballast circuit is complemented with a transformer T_1 whose primary winding T_{1a} is connected in series with a resonant-circuit capacitor C_R . Also in series with the primary winding T_{1a} of the transformer is connected a capacitor C_{DC2} . In parallel with the capacitor C_{DC2} and the primary winding of transformer T_1 is connected a switch transistor S_3 . In parallel with transistor S_3 is a diode D_1 that may be integral with the switch component as in a MOS-FET switch or a discrete component. The secondary windings T_{1b} and T_{1c} of the transformer are connected in parallel with the lamp cathodes. Between the cathodes and the secondary windings T_{1b} , T_{1c} may be connected auxiliary components (capacitors, diodes, etc.)

that are necessary for certain functional purposes. As the lamp load circuit branches via a conductor from the common point of the resonant-circuit components, that is, inductor L_R and capacitor C_R to the other lamp cathode, from this branching point onward the lamp ignition circuit and lamp load circuit are in a parallel connection.

[0008] The function of the above-described circuit is as follows. On preheating, switch S_3 is open and during the operation of half-bridge S_1 , S_2 the current passing through the resonant-circuit capacitor C_R also passes via the transformer primary winding T_{1a} . When the circuit is started, capacitor C_{DC2} charges up to a voltage at which the time integral of voltage over the transformer primary winding is zero. Depending on the cathode resistance, diode D_1 that is in parallel with switch S_3 either clips or does not clip the voltage to zero at the terminal of capacitor C_R which is connected to the switch. This condition is determined from the resistance of the lamp cathodes. Alternatively, the circuit may use a combination of diode D_2 and zener diode D_3 for clipping the positive half-wave of the voltage. The zener diode may also be replaced by a voltage reference or an adjustable shunt regulator.

[0009] When current passes via the transformer primary winding T_{1a} , the drive current to the cathodes is multiplied by the turns ratio of the transformer windings. This current heats the cathodes to a temperature at which the lamp can be ignited. Just prior to striking, switch S_3 is set on, whereby no voltage exists over the transformer primary winding and the circuit begins to operate as a conventional lamp load circuit, whereby no heating current is any more unnecessarily applied to the cathodes.

[0010] The drive current to the fluorescent lamp cathodes can be sensed at the transformer primary winding T_{1a} . The drive voltage to the fluorescent lamp cathodes may also be sensed from the voltage over the transformer primary winding T_{1a} . Sensing of drive voltage and current at both cathodes separately is not necessary inasmuch the cathode drive circuit is self-regulating so that when the resistance of the hotter cathode increases, the colder cathode receives more current. Failure at one cathode can be detected from a significant change at the transformer primary winding.

[0011] Changes in the resistance of the fluorescent lamp cathodes during heating can be sensed by way of sensing both the drive current to the cathodes and the drive voltage to the cathodes in the beginning of the heating cycle and then comparing the resistance value obtained based on these values with the corresponding values sensed and computed during heating.

[0012] In FIG. 2 is shown the voltage waveform measured from the common point between the resonant-circuit inductor L_R and capacitor C_R to the ground potential of the supply voltage during a typical preheating cycle. In FIG. 3 is shown typical voltage waveforms over the primary winding T_{1a} and secondary winding T_{1b} of transformer T_1 during the preheating cycle when the cathode

resistance is low.

[0013] FIG. 4 shows the corresponding situation for a high cathode resistance. Herein the primary voltage is clipped by both diodes D_1 and D_2 .

[0014] The circuit configuration according to the invention may be utilized particularly advantageously for controlling the heating current of lamp cathodes. The heating current can be adjusted to a desired level by driving switch S_3 ON and OFF with a pulse-width-controlled drive signal. The operating frequency of switch S_3 can be synchronized to the lamp operating frequency.

[0015] In FIG. 5 is shown by way of an exemplary embodiment the sense/control arrangement during the preheating cycle and immediately thereafter.

[0016] In the circuit of FIG. 5, a control block A can sense the cathode drive voltage V_{kat} during the preheating cycle. The voltage over the lamp cathodes can be sensed from the primary winding of transformer T_1 inasmuch the same voltage waveform appears over the different windings of the transformed scaled in turns ratio of the windings. Advantageously, the control block A incorporates a circuit or a stored program, wherein a limit is set for the drive voltages of the cathodes at which they are assumed to have reached a sufficiently high temperature for striking the lamp. When this limit is attained, control block A opens switch S_3 via control line OHJ3 thus terminating the preheating cycle. Thereupon, the control block commences the ignition cycle by controlling the operating frequency of switches S_1 and S_2 so that the voltage generated by the resonant circuit L_{R1} , C_R rises to a level sufficient for striking the lamp.

[0017] Immediately in the beginning of the preheating cycle, not only the cathode drive voltage but also the cathode drive current is sensed. Control block A incorporates a circuit or stored program capable of resolving the resistance of the cathodes from the sensed values. During the preheating cycle, control block A can then determine from the sensed values the instant of a sufficiently high increase of the cathode resistance to allow the control block A to terminate the preheating cycle. As the resistances of the cathodes are proportional to their temperatures, the ignition cycle can be commenced by the ballast as soon as the cathodes have reached their proper striking temperatures.

[0018] The common heating current of the cathodes can be either sensed separately from transformer current or inferred by the logic of the control block from control frequency of the switches S_1 and S_2 and the known values of the resonant-circuit components C_R and L_R and the input voltage.

[0019] In FIG. 6 is elucidated how the sensed values obtained according to the invention and the control functions based thereon can be used in a controllable ballast at low levels of illumination.

[0020] When the luminous output of a lamp is adjusted to a sufficiently low level, the discharge current through the lamp becomes insufficient to keep to the

cathodes at a temperature that can sustain the arc, but rather, supplemental heating power is needed to keep them hot. In the circuit configuration shown in FIG. 5, the heating voltage applied to the cathodes can be kept at a constant level by way of sensing the voltage V_{kat} over the transformer primary winding and then based thereon controlling the ON time of S_3 . Herein, the control can be effected dynamically pulse by pulse. In FIG. 6 is shown at two control levels the voltage waveform over the transformer primary winding (upper diagrams) and the corresponding control signals of switch S_3 (lower diagrams).

Claims

1. An electronic ballast for a fluorescent lamp, the ballast comprising

- an inverter supplied from a DC voltage source (V_{DC}) and including two power switch elements (S_1 , S_2) in a half-bridge totem-pole configuration for generating a high-frequency voltage,
- a lamp load circuit which is connected to the inverter and comprising an inductor (L_R) and a capacitor (C_R) in a series connection so as to form a series-resonant circuit and to which circuit the fluorescent lamp can be connected, and
- a heating circuit of the fluorescent lamp cathodes, the heating circuit including a transformer having a primary winding (T_{1a}) in series with the capacitor (C_R) of the resonant circuit and at least two secondary windings (T_{1b} , T_{1c}) connected in parallel with the cathodes of the fluorescent lamp, the lamp being adapted connectable in parallel with the series connection of the capacitor (C_R) of the resonant circuit and the transformer primary winding (T_{1a}),

characterized in that the heating current drive to the lamp cathodes is arranged to take place via said secondary windings (T_{1b} , T_{1c}) such that each of the lamp cathodes is driven by its own secondary winding, and that in parallel with said primary winding (T_{1a}) is disposed a switch element (S_3) whose setting in an ON condition shuts off the heating current passed via said secondary windings (T_{1b} , T_{1c}).

2. A ballast according to claim 1, **characterized in that** the heating current is adapted controllable to a desired level by driving the switch (S_3) ON and OFF with a pulse-width-controlled drive signal.

3. A ballast according to claim 2, **characterized in that** the operating frequency of switch (S_3) is synchronized to the operating frequency of lamp load circuit.

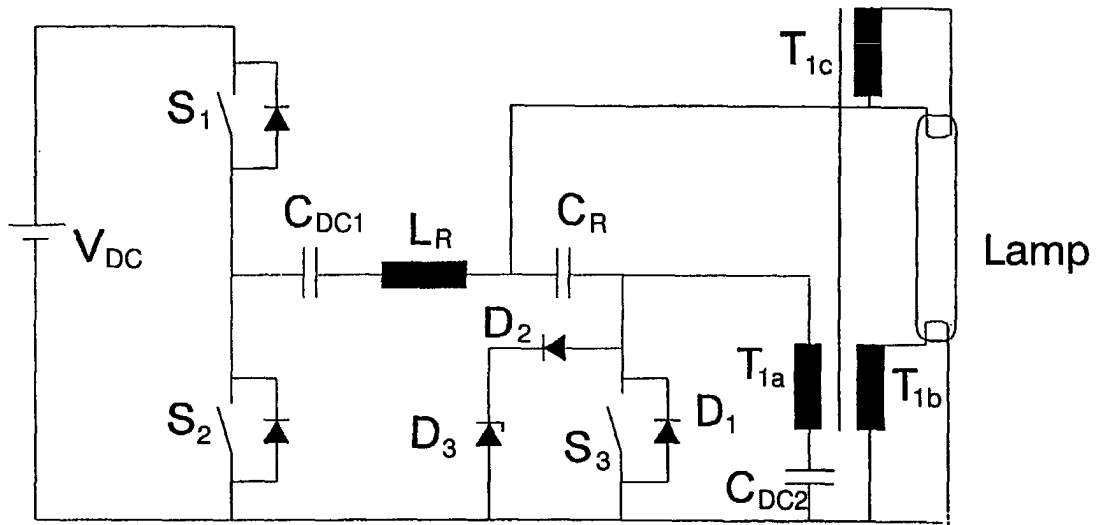
4. A ballast according to any one of claims 1 - 3, **characterized in that** the sensing of the drive current (I_{kat}) to the fluorescent lamp cathodes is arranged to take place at the primary winding (T_{1a}) of the transformer.

5. A ballast according to any one of claims 1 - 4, **characterized in that** the sensing of the drive voltage (V_{kat}) to the fluorescent lamp cathodes is arranged to take place from voltage of the primary winding (T_{1a}) of the transformer.

6. A ballast according to claims 4 and 5, **characterized in that** the sensing of changes in the resistance of the fluorescent lamp cathodes during heating cycle is arranged to take place by way of sensing both the drive current of the cathodes and the drive voltage of the cathodes in the beginning of the heating cycle and then comparing the resistance value obtained based on these values with the corresponding values sensed and computed during heating.

7. A ballast according to any one of claims 1 - 6, **characterized in that**, in order to limit the cathode drive voltage, in parallel with the primary winding (T_{1a}) of the transformer are connected components (D_2 , D_3) for clipping the positive half-wave of the voltage.

8. A ballast according to any one of claims 1-7, **characterized in that** the heating current drive to the lamp cathodes is arranged to take place solely via said secondary windings (T_{1b} , T_{1c}).



Schematic diagram of a heating circuit for the cathodes of a fluorescent lamp

Fig.1

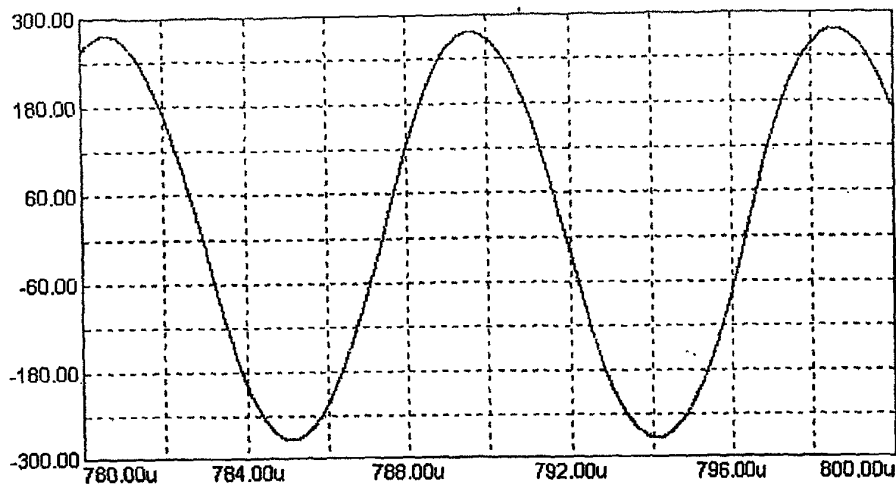


Fig.2

Voltage at common point of resonant circuit capacitor and inductor referenced to ground potential of supply voltage during preheating cycle.

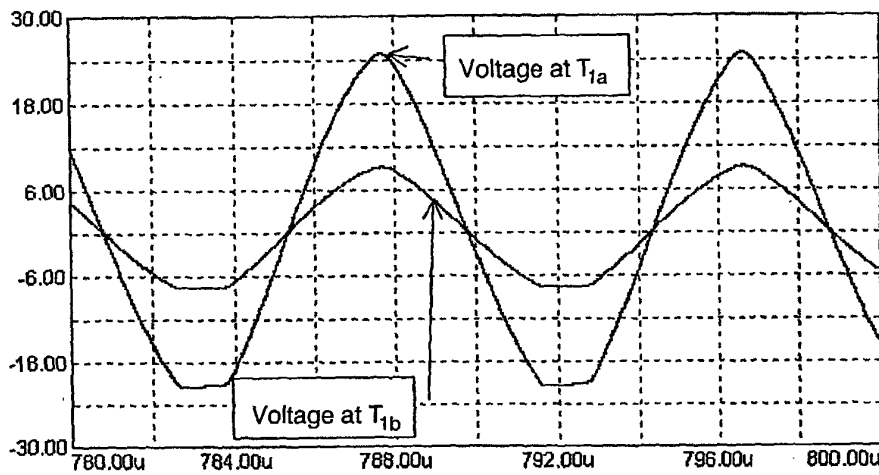


Fig.3

Primary and secondary voltages of transformer T_1 for a low cathode resistance.

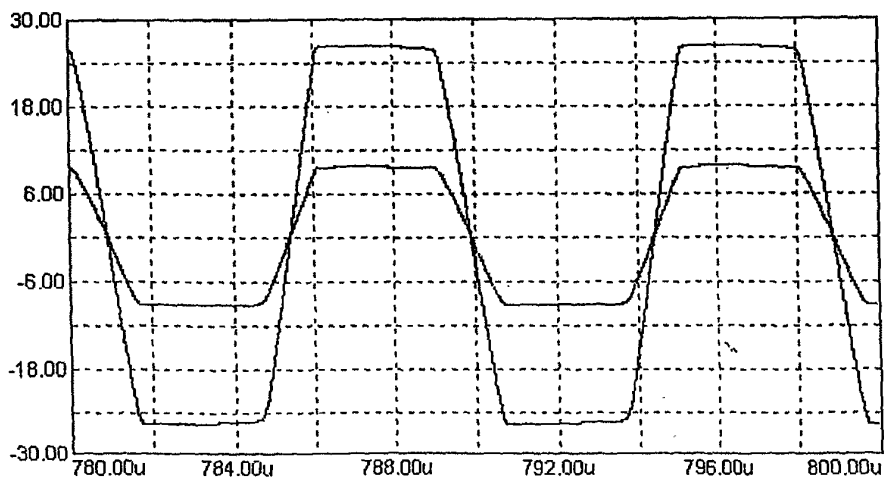
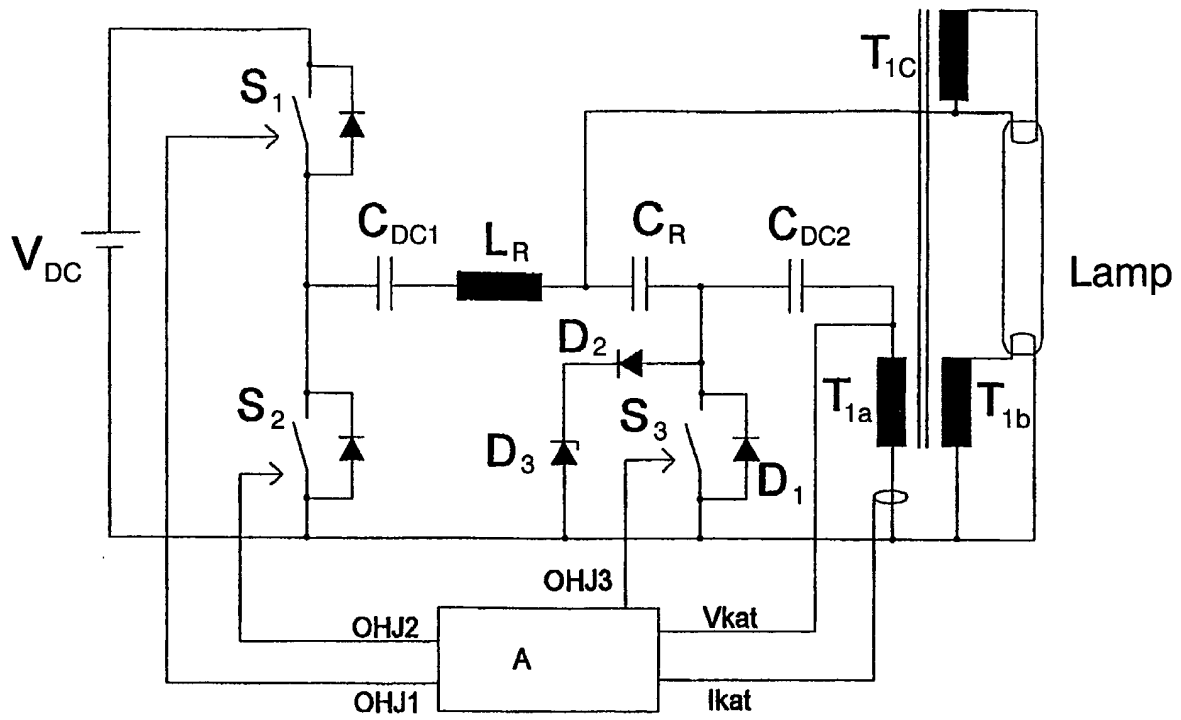


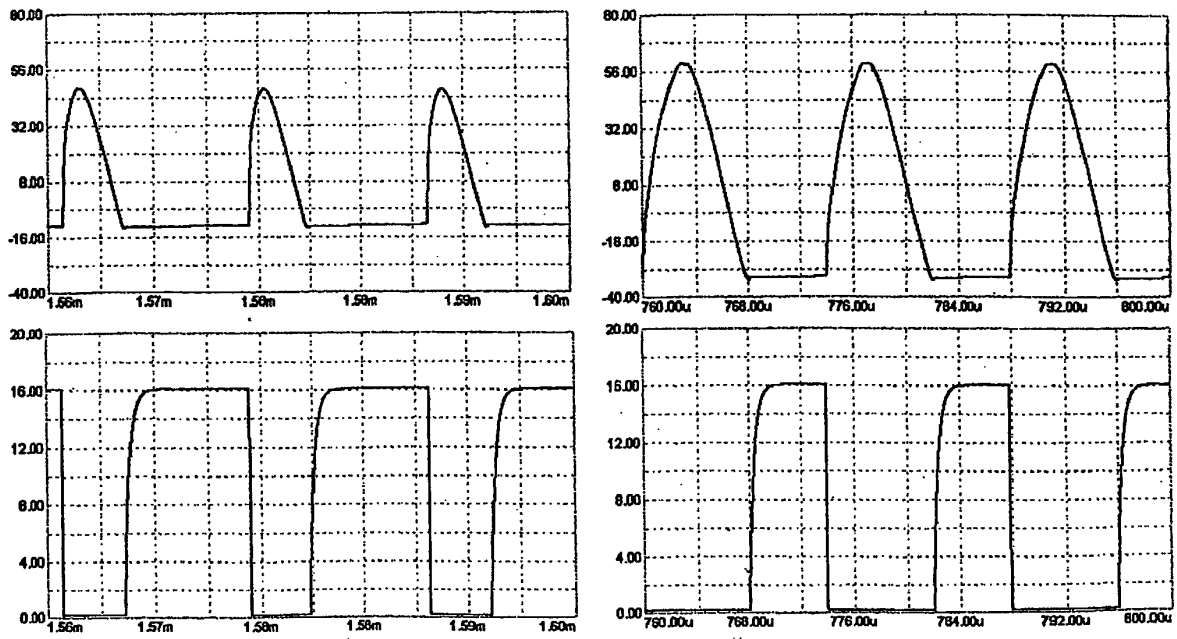
Fig.4

Primary and secondary voltages of transformer T_1 for high cathode resistance



Sense and control signals of cathode heating circuit

Fig.5



Voltage over primary winding T_{1a} of transformer T_1 at two different power control levels and the control signals of switch S_3 connected over the winding.

Fig.6