



## Electronic Transformer

The present invention concerns an electronic transformer or, that is to say, an electronic converter, for operating at least one low-voltage halogen lamp according to the pre-characterising clause of Claim 1.

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The basic principle of such types of electronic transformers is known from C.H. Sturm/E. Klein "Betriebsgeräte und Schaltungen für elektrische Lampen", Siemens Aktiengesellschaft, 1992, pages 295 ff. Their  
10 general construction, as well as the mode of operation, is illustrated in Fig. 3. First of all, the electronic transformer has a harmonic filter 1 for radio interference suppression, which at the input side is connected to an alternating voltage source, which in the present example,  
15 outputs an alternating supply voltage at a frequency of 50 Hz. Connected to the harmonic filter 1 is a rectifier circuit 2, for example a simple diode circuit, which rectifies the alternating supply voltage. The rectified intermediate circuit voltage produced by the rectifier  
20 circuit 2 is finally fed to an inverter 3, which in the usual manner has two switches - for example power transistors - arranged in a half-bridge circuit, which, according to a specific layout, are switched on and off alternately, so that in this way a voltage that is chopped  
25 into rectangular blocks is produced, which is modulated by the rectified mains voltage. The alternating voltage thus produced is transmitted via a transformer 4 to an output-side load circuit and in so doing is transformed into the extra-low voltage required for the low-voltage halogen lamp  
30 L arranged in the load circuit. Furthermore, an additional circuit 5 for rectifying, as well as a filter 6 for smoothing the transmitted alternating voltage, is located in the load circuit.

35 Apart from their basic function - to convert the voltage delivered by the supply system into an extra-low voltage suitable for the low-voltage halogen lamp - electronic



transformers also offer the possibility of operating the lamp in a dimmed mode. The most widely used method for dimming is so-called phase-angle control in which, according to the desired degree of dimming, the two  
5 switches of the inverter are triggered during one half-cycle of the rectified alternating supply voltage for only a specific time period. In this so-called internal dimming of electronic transformers, because of the phase segment large voltage transients can of course occur, which in turn  
10 - since they have a frequency corresponding to the alternating supply voltage - can lead to clearly audible noise.

The object of the present invention is therefore to specify  
15 an electronic transformer for operating at least one low-voltage halogen lamp, in which noiseless dimming of the lamp is made possible.

This object is achieved by an electronic transformer  
20 according to Claim 1 or by a process for operating a low-voltage halogen lamp according to Claim 6. According to the invention, the dimming is effected in such a way that the mark-space-ratio for both switches of the inverter is varied, in that the delay time between the opening  
25 (switching off) of one of the two switches and the following closing (switching on) of the other switch remains constant and the on-time is shortened in each case. With this process, in which the two switches of the inverter are constantly triggered, the large voltage  
30 transients occurring in phase-angle control can be avoided. Only the switching frequencies for the two switches are varied so that a reduced r.m.s. voltage corresponding to the desired degree of dimming appears at the output side of the transformer.

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In comparison with the other dimming processes, in the case of the process according to the invention, during dimming

the switching frequencies are increased by the reduction in the on-times, so that it is possible to operate the half-bridge switches independently of the degree of dimming, in a frequency range that lies above the human limit of audibility and thus causes no noise nuisance. Preferably, both switches are operated in a frequency range between 35 kHz - for the undimmed state - and 300 kHz - for maximum dimming. Moreover, the switches are preferably driven so that their mark-space-ratio is identical.

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Maintaining the delay time constant also offers the possibility of triggering the two switches of the inverter in such a way that, irrespective of the set degree of dimming, they each switch at a time instant at which no voltage is applied to them. This corresponds to so-called zero voltage switching in which turn-on losses are avoided. Thus, due to the present invention, an electronic transformer for operating a low-voltage halogen lamp is specified, which on the one hand has a high efficiency and on the other hand facilitates a noiseless dimming of the lamp.

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The invention will now be explained in further detail below by way of example with the aid of the accompanying drawings, in which:

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Fig. 1 shows the inverter, transformer and load circuit of the electronic transformer according to the invention;

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Fig. 2 Shows the triggering according to the invention of the two switches of the inverter; and

Fig. 3 shows the general construction of an electronic transformer, as it is known from the prior art.

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The alternating supply voltage rectified by the rectifier (not shown) is applied to the input of the inverter illustrated in Fig. 1. The triggering of the two switches V1 and V2 arranged in a half-bridge arrangement, which involves power transistors or field-effect transistors, is effected by a half-bridge driver HB, which in turn is controlled by a control circuit  $\mu C$  in the form of a microprocessor. The two switches V1 and V2 are switched on and off alternately, so that at the interconnection point between the two half-bridge capacitors C2 and C3, which are connected in parallel with the two field-effect transistors V1 and V2, a square-wave voltage appears that is modulated by the rectified and half-sinewave intermediate circuit voltage. This alternating voltage is transmitted to the load circuit by the primary winding  $T_p$  of a transformer arranged between the interconnecting points of the two switches V1 and V2 and of the two intermediate circuit capacitors C2 and C3. The choke L1 ensures commutation of the current at the secondary side, the capacitor C1 suppresses high-frequency interference.

In the load circuit are located two secondary windings Ts1 and Ts2 of the transformer, to whose common node point the low-voltage halogen lamp L is connected. As an alternative to this, a single secondary winding with a centre tap can also be provided. Between the secondary windings Ts1 and Ts2 and the low-voltage halogen lamp L is located an LC element formed by a coil L2 and a capacitor C4 and acting as a low-pass filter for smoothing the high-frequency alternating voltage. Furthermore, the load circuit has two diodes D1 and D2, which are arranged in the form of a full-wave rectifier in order to rectify the alternating voltage fed to the low-voltage halogen lamp L.

The triggering according to the invention of the two half-bridge switches V1 and V2 will be explained in more detail below with the aid of Fig. 2, which illustrates the

switching states of the two switches for two different dimming stages. Here the upper timing diagram in Fig. 2 shows the switching states of the two half-bridge switches in the undimmed state - the full line for the switch V1 and  
5 the broken line for the switch V2 - while the lower timing diagram illustrates the switching states in a dimmed state.

As already explained, both switches are triggered in such a way that they are switched on or conducting (state 1) and  
10 switched off or non-conducting (state 0) alternately, a certain delay time  $t_{del}$  remaining between the opening of one switch and the following closing of the other switch, during which time both switches are switched off. This delay time, among other things, ensures that no short-  
15 circuit can occur due to a simultaneous closing of both switches of the half-bridge. Furthermore, it can of course also happen that each of the two switches switch on without losses at a time instant at which no voltage is applied to them, since due to the reactances contained in the circuit  
20 a certain time elapses until the voltage ratios rotate. Such lossless switching is also termed "zero switching loss" or "zero voltage switch" and can lead to an appreciable increase in the efficiency.

25 The mark-space-ratio for the two switches is determined by the ratio between the on-time  $t_{on}$  and the off-time  $t_{off}$ . Here a highest possible mark-space-ratio is selected for the undimmed state illustrated above, which preferably corresponds to a switching frequency  $f$  of approximately 35  
30 kHz, the same mark-space-ratio being set for both switches.

According to the invention, the dimming of the low-voltage halogen lamp occurs in such a way that the duration of the delay time  $t_{del}$  is retained and only the on-time  $t_{on}$  is  
35 equally reduced for both switches. As a result of this, the switching frequency  $f$  is on the whole increased, as can be seen in the lower timing diagram in Fig. 2. If, for

example, in the undimmed state at a frequency of 35 kHz an output-side voltage of 12 volts r.m.s. is obtained, then by increasing the switching frequency to 300 kHz, a reduction in the output-side voltage of 4 volts r.m.s. can be  
5 achieved, which results in the low-voltage halogen lamp being set to approximately 1 % of its maximum light output. Generally speaking, the entire dimming range for the low-voltage halogen lamp can essentially be covered by increasing the base frequency, that is to say the frequency  
10 existing in the undimmed mode, by the factor of 7 to 12.

In contrast to the previously known processes, the switching frequency is again increased by the dimming, so that it is shifted into a frequency range that is far  
15 removed from the human limit of audibility. Since in the undimmed state the existing 35 kHz already lies in the ultrasonic range, and therefore is usually imperceptible, a simple and effective dimming that leads to no noise nuisance is realised in this manner. Since, however, as  
20 before, the delay time  $t_{del}$  is held constant, zero switching can also be achieved in the dimmed state for the two half-bridge switches, so that the electronic transformer according to the invention has an extraordinarily high efficiency.

Claims

1. Electronic transformer for operating at least one low-voltage halogen lamp (L),  
having an inverter (3) with two switches (V1, V2) capable of being switched on and off, for providing an alternating output voltage,  
having a control circuit ( $\mu C$ ) for controlling the on and off switching behaviour of the two switches (V1, V2) of the inverter, and  
having a transformer (4,  $T_p$ ,  $T_{s1}$ ,  $T_{s2}$ ), that at the input side is connected to the inverter (3) and to which at the output side is connected a load circuit having the at least one low-voltage halogen lamp (L),  
**characterised in that,**  
the control circuit ( $\mu C$ ) for dimming the at least one low-voltage halogen lamp (L) varies the mark-space-ratio for both switches (V1, V2) in such a way that the delay time ( $t_{del}$ ) between the opening of one of the two switches (V1) and the following closing of the other switch (V2) remains constant and the on-time ( $t_{on}$ ) is shortened in each case.
2. Electronic transformer according to Claim 1,  
**characterised in that,**  
irrespective of the degree of dimming, the switching frequencies of the two switches (V1, V2) lie above the human limit of audibility.
3. Electronic transformer according to Claim 2,  
**characterised in that,**  
at maximum dimming, the switching frequency of the two switches (V1, V2) is approximately 10 times higher than the switching frequency in the undimmed mode.

4. Electronic transformer according to Claim 3,  
**characterised in that,**  
the switching frequencies of the two switches (V1, V2) lie  
between 35 kHz and 300 kHz.

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5. Electronic transformer according to one of the  
preceding Claims,

**characterised in that,**

the mark-space-ratio is identical for both  
10 switches (V1, V2).

6. Process for operating at least one low-voltage halogen  
lamp (L) by means of an electronic transformer, comprising  
an inverter (3) with two switches (V1, V2) capable of  
15 being switched on and off, for providing an alternating  
output voltage,

a control circuit ( $\mu C$ ) for controlling the on and off  
switching behaviour of the two switches (V1, V2) of the  
inverter, and

20 a transformer (4,  $T_p$ ,  $T_{s1}$ ,  $T_{s2}$ ), that at the input  
side is connected to the inverter (3) and to which at the  
output side is connected a load circuit having the at least  
one low-voltage halogen lamp (L),

**characterised in that,**

25 for dimming the at least one low-voltage halogen lamp (L)  
the mark-space-ratio for both switches (V1, V2) is varied  
in such a way that the delay time ( $t_{del}$ ) between the opening  
of one of the two switches (V1) and the following closing  
of the other switch (V2) remains constant and the on-time  
30 ( $t_{on}$ ) is shortened in each case.

7. Process according to Claim 6,

**characterised in that,**

irrespective of the degree of dimming, the switching  
35 frequencies of the two switches (V1, V2) lie above the  
human limit of audibility.

8. Process according to Claim 6 or 7,  
**characterised in that,**  
at maximum dimming, the switching frequency of the two  
switches (V1, V2) is approximately 10 times higher than the  
5 switching frequency in the undimmed mode.

9. Process according to Claim 8,  
**characterised in that,**  
the switching frequencies of the two switches (V1, V2) lie  
10 between 35 kHz and 300 kHz.

10. Process according to one of Claims 5 to 9,  
**characterised in that,**  
the mark-space-ratio is identical for both  
15 switches (V1, V2).