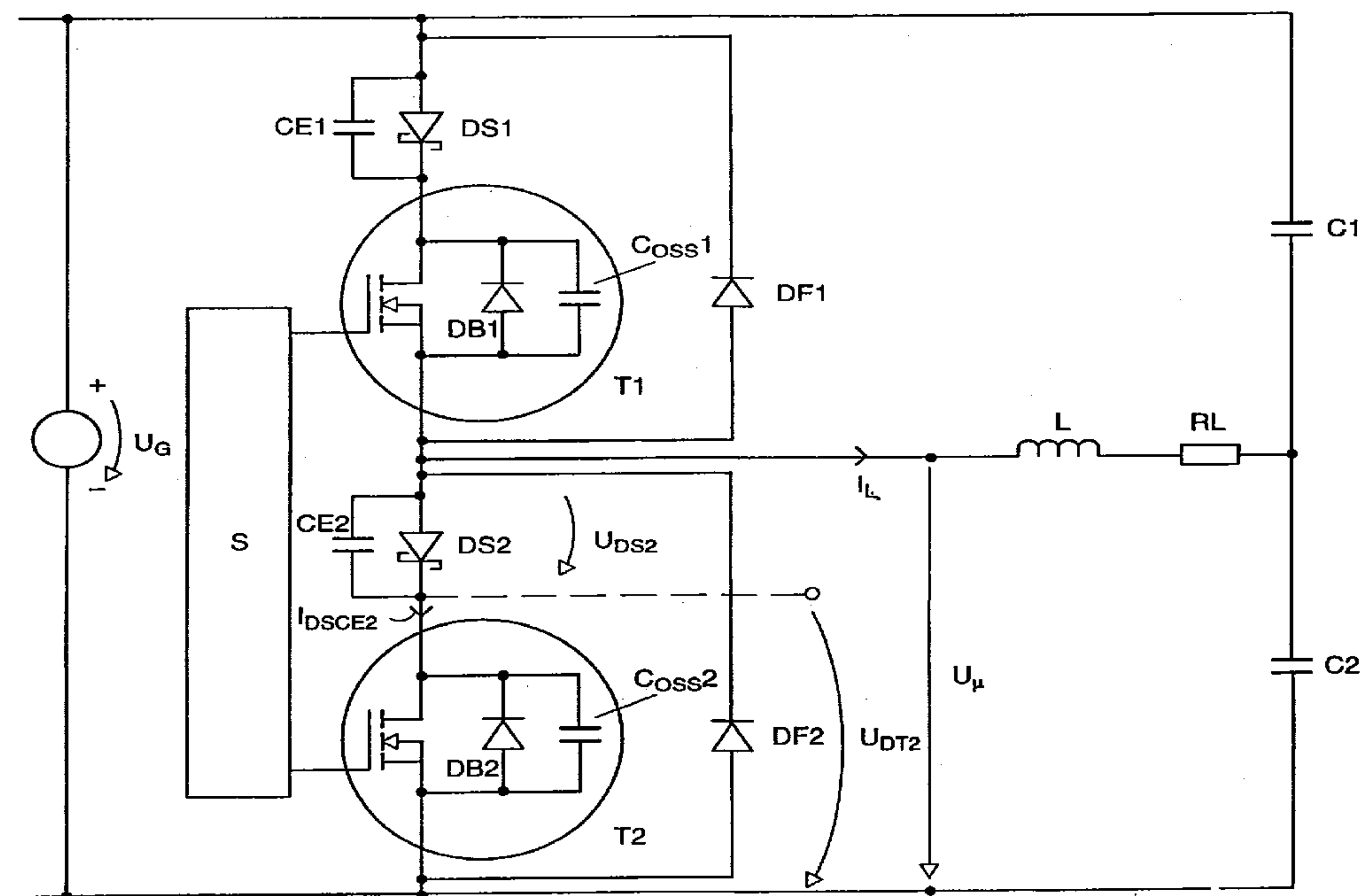




- (72) LIMMER, WALTER, DE  
(72) HUBER, ANDREAS, DE  
(72) NIEDERMEIER, PETER, DE  
(71) PATENT-TREUHAND-GESELLSCHAFT FÜR ELEKTRISCHE  
GLUEHLAMPEN MBH, DE  
(51) Int.Cl.<sup>7</sup> H03H 11/00, H02P 7/292, H05B 41/14  
(30) 1999/04/16 (199 17 364.8) DE  
(54) **ENSEMBLE DE CIRCUIT A DEMI-PONT**  
(54) **CIRCUIT ARRANGEMENT WITH HALF-BRIDGE**



(57) The invention relates to a circuit arrangement having a half-bridge arrangement comprising a first and a second switch (T1;T2), each switch (T1;T2) having, between its operating and reference electrodes, an internal diode (DB1;DB2), which is reverse-connected in parallel with the main current flow direction of the respective switch (T1;T2), and also an internal capacitance ( $C_{oss1}$ ;  $C_{oss2}$ ), a series diode (DS1; DS2) being arranged in series with the respective switch (T1;T2) in the main current flow direction in such a way that current can flow in the main current flow direction, and a freewheeling diode (DF1;DF2) being connected in parallel with the respective series circuit formed by the switch (T1;T2) and the series diode (DS1;DS2), and having a load circuit (L;RL), which has at least one inductive component (L) and is connected to the midpoint of the half-bridge arrangement. In order to reduce the failure rate of the series diodes (DS1; DS2), a load-relieving capacitance (CE1;CE2) is connected in parallel with each series diode (DS1;DS2).



**Abstract**

The invention relates to a circuit arrangement having a half-bridge arrangement comprising a first and a second switch (T1;T2), each switch (T1;T2) having, between its operating and reference electrodes, an internal diode (DB1;DB2), which is reverse-connected in parallel with the main current flow direction of the respective switch (T1;T2), and also an internal capacitance (Coss1;Coss2), a series diode (DS1;DS2) being arranged in series with the respective switch (T1;T2) in the main current flow direction in such a way that current can flow in the main current flow direction, and a freewheeling diode (DF1;DF2) being connected in parallel with the respective series circuit formed by the switch (T1;T2) and the series diode (DS1;DS2), and having a load circuit (L;RL), which has at least one inductive component (L) and is connected to the midpoint of the half-bridge arrangement. In order to reduce the failure rate of the series diodes (DS1;DS2), a load-relieving capacitance (CE1;CE2) is connected in parallel with each series diode (DS1;DS2).

Figure 4

**Circuit arrangement with half-bridge**

5

The present invention relates to a circuit arrangement having a half-bridge arrangement comprising a first and a second switch, each switch having, between its operating and reference electrodes, an internal diode, which is reverse-connected in parallel with the main current flow direction of the respective switch, and also an internal capacitance, a series diode being arranged in series with the respective switch in the main current flow direction in such a way that current can flow in the main current flow direction, and a freewheeling diode being connected in parallel with the respective series circuit formed by the switch and the series diode, and having a load circuit, which has at least one inductive component and is connected to the midpoint of the half-bridge arrangement.

20

Such a circuit arrangement, disclosed in the prior art, is illustrated in Figure 1. It will be used to illustrate the problem on which the invention is based.

25

Figure 1 shows the part which is of interest, in the context of the present invention, of a circuit arrangement which can be found in a wide variety of fields appertaining to electronics, for example in step-down controllers, DC motor power converters and three-phase motor power converters, etc. It comprises a half-bridge arrangement with two switches T1 and T2, in this instance MOSFET transistors, which are fed from a DC voltage source  $U_G$ , for example an intermediate circuit voltage. In order to comprehend the considerations which lead to the circuit illustrated in Figure 1, the circuit illustrated in Figure 1 will first be considered without the series diodes DS1 and DS2 arranged in series with the switches T1 and T2, and the freewheeling diodes DF1 and DF2 connected in

35  
40

parallel with the respective combination formed by series diode and switch. A load circuit is connected to the midpoint of the half-bridge, said load circuit having an inductive component, schematically  
5 illustrated as a series circuit formed by an inductance  $L$  and a non-reactive resistance  $R_L$ , through both of which the load current  $I_L$  flows. The load circuit is furthermore connected to the midpoint of two series-connected capacitors  $C_1$ ,  $C_2$ , which are arranged  
10 in parallel with the half-bridge switches  $T_1$  and  $T_2$ . The half-bridge switches  $T_1$  and  $T_2$  are driven by a control device  $S$ , illustrated schematically. Figure 2 shows an equivalent circuit diagram of a MOSFET, revealing that the drain and source have arranged  
15 between them a so-called body diode  $DB$ , which is reverse-connected in parallel with the main current flow direction from the drain to the source, and an output capacitance  $C_{oss}$  in parallel with said diode. Figure 3 shows the time characteristic of the load  
20 current  $I_L$  for exemplary driving of the half-bridge arrangement by the control device  $S$ . During phase 1, the transistor  $T_2$  is switched off and the transistor  $T_1$  is alternately switched on and off, whereas this is reversed in phase 2. During the phase section 1a, which  
25 is shown enlarged, the current flows in the mesh -  $U_G$   $T_1$   $L$   $R_L$   $C_2$ , and, during the phase section 1b, the load current flows further in the mesh  $L$   $R_L$   $C_2$   $T_2$  after  $T_1$  has been switched off,  $T_2$  remaining switched off, on account of the inductive component of the load circuit.  
30 This is made possible by the body diode  $DB$  of the switch  $T_2$ . With regard to its electric properties, the body diode  $DB$  inherent to the transistor  $T_2$  is characterized by a very slow turn-off time and a low forward voltage. If  $T_1$  is then switched on again after  
35 phase 1b, in other words the voltage  $U_\mu$  equal to  $U_G$  is present at the midpoint of the half-bridge, then a current flows briefly via the body diode  $DB$  of the transistor  $T_2$ , which current could be referred to as a short-circuit current, which leads to a high power loss

converted in the transistor. This leads to internal and external interference with such a circuit arrangement, for example in the EMC range.

5 In order to improve the reliability of such a circuit and in order to avoid the necessity of shields for suppressing interference, the prior art has provided for arranging a series diode DS1 or DS2, respectively, in series with each switch, said diodes preferably  
10 being realized as Schottky diodes since these diodes typically have a low forward voltage, and which diodes are oriented in such a way as to enable current to flow in the main current flow direction of the respective switch. As a consequence, therefore, the respective  
15 series diode DS1 or DS2, respectively, and the associated body diode DB1 or DB2, respectively, (also see Figure 4 in this respect) are reverse-connected in series, which is why current is prevented from flowing through the respective body diode during the  
20 freewheeling process (phase 1B of Figure 3). Since the function of the body diode inherent to the MOSFET is accordingly prevented by the respective series diode, it is necessary to provide a freewheeling diode DF1 or DF2, respectively, which is arranged in parallel with  
25 said combination and now undertakes the original function of the respective body diode.

In practice, however, it has now been shown that, in the case of a circuit arrangement of this type, one of  
30 the two diodes DS1 or DS2 frequently fails.

The object of the present invention, therefore, is to improve a circuit arrangement of the type mentioned in the introduction, as is illustrated in Figure 1, in  
35 such a way that the failure rate of the series diodes DS1 and/or DS2 is reduced.

This object is achieved by virtue of the fact that a load-relieving capacitance is connected in parallel

with each series diode. This measure, the function of which is explained in detail further below, leads not only to a significantly reduced failure rate of the diodes DS1 and/or DS2, but also to a reduction in the power loss converted in the circuit. It also enables the use of smaller and thus less expensive diodes for the series diodes DS1 and DS2.

The solution according to the invention can preferably be applied to half-bridge arrangements whose switches are realized by a MOSFET, in which case, as mentioned, the respective internal diode is formed by the respective body diode and the respective internal capacitance is formed by the respective output capacitance  $C_{oss}$ . This fact notwithstanding, the solution according to the invention can also be used in circuit arrangements in which these components, which are parasitic components of a MOSFET, are engendered by a different combination.

Each load-relieving capacitance is preferably dimensioned in such a way that the voltage dropped during operation of the circuit arrangement across the load-relieving capacitance of the respective voltage divider essentially formed from the load-relieving capacitance and the internal capacitance is always smaller than the reverse voltage of the respective series diode. The load-relieving capacitance is preferably 100 pF to 10 nF.

It goes without saying that the application of the invention is not limited to half-bridge arrangements, but rather can be realized with the use of two further switches in a full-bridge arrangement, the load circuit being coupled between the midpoints of the switches.

The solution according to the invention can also be realized, with the half-bridge arrangement being supplemented by four further switches, in a three-phase

bridge to which the load circuit is coupled. In this respect, diverse areas of use emerge, mention being made, by way of example, of step-down controllers, as are used in ballasts for operating discharge lamps, DC motor power converters and three-phase motor power converters.

Further advantageous developments of the invention are defined in the subclaims.

10

An exemplary embodiment is described in more detail below with reference to the accompanying drawings, in which:

15 Figure 1 illustrates a circuit arrangement disclosed in the prior art;

Figure 2 illustrates an equivalent circuit diagram for a MOSFET;

20

Figure 3 illustrates the time sequence of the load current  $I_L$  in the event of corresponding driving of the circuit arrangement in accordance with Figure 1;

25

Figure 4 illustrates a circuit arrangement in which the solution according to the invention is realized;

30 Figure 5 illustrates time characteristics of the voltages  $U_{\mu}$ ,  $U_{DT2}$ ,  $U_{DS2}$  and of the current  $I_{DSCE2}$  of the circuit arrangements in accordance with Figures 1 and 4 in the event of corresponding driving.

35

Figure 4 shows a circuit arrangement according to the invention, in which the same structural elements as in Figure 1 and in the equivalent circuit diagram in accordance with Figure 2 are designated by the same

reference symbols. Load-relieving capacitances CE1 and CE2 are connected in parallel with the series diodes DS1 and DS2; said load-relieving capacitances will be disregarded in the first instance for the  
5 considerations below. On account of the switching of the transistors T1 and/or T2 and the inductive part of the load circuit, the potential  $U_{\mu}$  of the half-bridge midpoint alternates between  $+U_G$  and ground. In this case, the respective drain terminal of the transistors  
10 T1 and T2 acts as the operating electrode and the respective source terminal as the reference electrode.

The steep switching edges during the transition of the potential  $U_{\mu}$  from 0 to  $U_G$  lead to a compensating current  
15  $I_{DSCE2}$  and to the charging of the capacitance  $C_{oss2}$ . The current  $I_{DSCE2}$  flows only through the Schottky diode DS2 in the case of Figure 1, but through the parallel circuit formed by the diode DS2 and the load-relieving capacitance CE2 in the case of Figure 4. Since  $U_{\mu}$  may be  
20 of the order of magnitude of a few hundred volts, or indeed even more than that, a considerable current  $I_{DSCE2}$  flows in this case, see Figure 5. More problematic, however, is the transition from a state in which  $U_{\mu}$  is equal to  $U_G$ , to  $U_{\mu}$  equal to 0. In this case, a negative  
25  $I_{DSCE2}$  flows for the discharge of the output capacitance  $C_{oss2}$ , that is to say, in the case of Figure 1, the diode DS2 is operated in the so-called avalanche mode. Avalanche mode means that a voltage is applied to the diode DS2 in the reverse direction which is larger than  
30 the reverse voltage of said diode, for which reason the diode DS2 permits a current flow in the reverse direction (negative  $I_{DSCE2}$ , see Figure 5). In the avalanche mode, the diode's own reverse voltage is dropped across it.

35

The avalanche mode appears to be the primary cause of the failure of the series diodes. In addition, however, this operating mode of the series diodes also leads to the conversion of a power loss in these diodes, namely

the product of reverse voltage of DS2 times current  $I_{DSCE2}$ .

The load-relieving capacitors CE1 and CE2, respectively, which are inserted in accordance with the invention act in the following manner: a negative current  $I_{DSCE2}$  charges the load-relieving capacitor CE2, connected in parallel with the series diode DS2, with a defined edge steepness. If the capacitor CE2 is dimensioned in a suitable manner, then it prevents the breakdown voltage of the diode DS2 from being reached. An avalanche mode of the series diode DS2 does not take place, therefore. During the subsequent jump in voltage of  $U_u$  from ground to  $+U_G$ , the load-relieving capacitor CE2 is discharged again.

The above explanations apply analogously to the series diode DS1 and the load-relieving capacitor CE1.

For the dimensioning of the respective load-relieving capacitance CE, the respective combination of series diode DS, load-relieving capacitor CE, body diode DB and output capacitance  $C_{oss}$  can be simplified to give a series circuit formed by load-relieving capacitor CE and output capacitance  $C_{oss}$ , since both diodes are in the turned-off state. The voltage divider comprising load-relieving capacitor CE and output capacitance  $C_{oss}$  is then advantageously dimensioned in such a way that the maximum voltage dropped across the load-relieving capacitor CE remains below the reverse voltage of the series diode DS connected in parallel with the load-relieving capacitor CE. The voltage dependence of the output capacitance  $C_{oss}$  must be taken into consideration in this case.

In addition to the intended effect, namely the reduction in the failure rate of the series diodes, this measure also has the consequence that active power is now no longer converted in the series diodes, rather

only reactive volt-amperes are shifted back and forth between load-relieving capacitor and output capacitance  $C_{oss}$ . This leads to a reduction in the evolution of heat by the circuit arrangement, with the associated advantages.

The present circuit has been described using the example of a half-bridge arrangement with an n-channel MOSFET, but, as is obvious to a person skilled in the art, it can also be realized using a p-channel MOSFET. Said circuit can readily be used in a full-bridge arrangement if the capacitors C1 and C2 are replaced by switches. As is discernible to a person skilled in the art, said circuit can also be applied to a three-phase motor power converter, in which case preferably four further switches are added to the half-bridge arrangement.

It is irrelevant to the method of operation of the invention whether the combination formed by the series diode DS and the load-relieving capacitance CE is connected to the associated switch on the operating electrode side or the reference electrode side.

**Patent Claims**

1. A circuit arrangement having  
- a half-bridge arrangement comprising a first and a  
5 second switch (T1;T2), each switch (T1;T2) having,  
between its operating and reference electrodes, an  
internal diode (DB1;DB2), which is  
reverse-connected in parallel with the main  
current flow direction of the respective switch  
10 (T1;T2), and also an internal capacitance  
(Coss1;Coss2), a series diode (DS1;DS2) being  
arranged in series with the respective switch  
(T1;T2) in the main current flow direction in such  
a way that current can flow in the main current  
15 flow direction, and a freewheeling diode (DF1;DF2)  
being connected in parallel with the respective  
series circuit formed by the switch (T1;T2) and  
the series diode (DS1;DS2), and  
- a load circuit (L;RL), which has at least one  
20 inductive component (L) and is connected to the  
midpoint of the half-bridge arrangement,  
wherein a load-relieving capacitance (CE1;CE2) is  
connected in parallel with each series diode (DS1;DS2).
- 25 2. The circuit arrangement as claimed in claim 1,  
wherein the first and second switches (T1;T2) of the  
half-bridge arrangement are realized by a MOSFET, the  
respective internal diode being formed by the  
respective body diode (DB1;DB2) and the respective  
30 internal capacitance being formed by the respective  
output capacitance (Coss1;Coss2).
3. The circuit arrangement as claimed in claim 1,  
wherein each load-relieving capacitance (CE1;CE2) is  
35 dimensioned in such a way that the voltage dropped  
during operation of the circuit arrangement across the  
load-relieving capacitance (CE1;CE2) of the respective  
voltage divider essentially formed from the  
load-relieving capacitance (CE1;CE2) and the internal

capacitance ( $C_{oss1};C_{oss2}$ ) is always smaller than the reverse voltage of the respective series diode ( $DS1;DS2$ ).

5 4. The circuit arrangement as claimed in claim 3, wherein the load-relieving capacitance ( $CE1;CE2$ ) is between 100 pF and 10 nF.

10 5. The circuit arrangement as claimed in claim 1, wherein the half-bridge arrangement and two further switches form a full-bridge arrangement between whose midpoints the load circuit ( $L;RL$ ) is coupled.

15 6. The circuit arrangement as claimed in claim 1, wherein the half-bridge arrangement and four further switches form a three-phase bridge to which the load is coupled.

20 7. A step-down controller having a circuit arrangement as claimed in one of claims 1 to 5.

8. A DC motor power converter having a circuit arrangement as claimed in one of claims 1 to 5.

25 9. A three-phase motor power converter having a circuit arrangement as claimed in one of claims 1 to 6.

10. A ballast for operating discharge lamps having a step-down controller as claimed in claim 7.

Smart & Biggar  
Ottawa, Canada  
Patent Agents

1/4

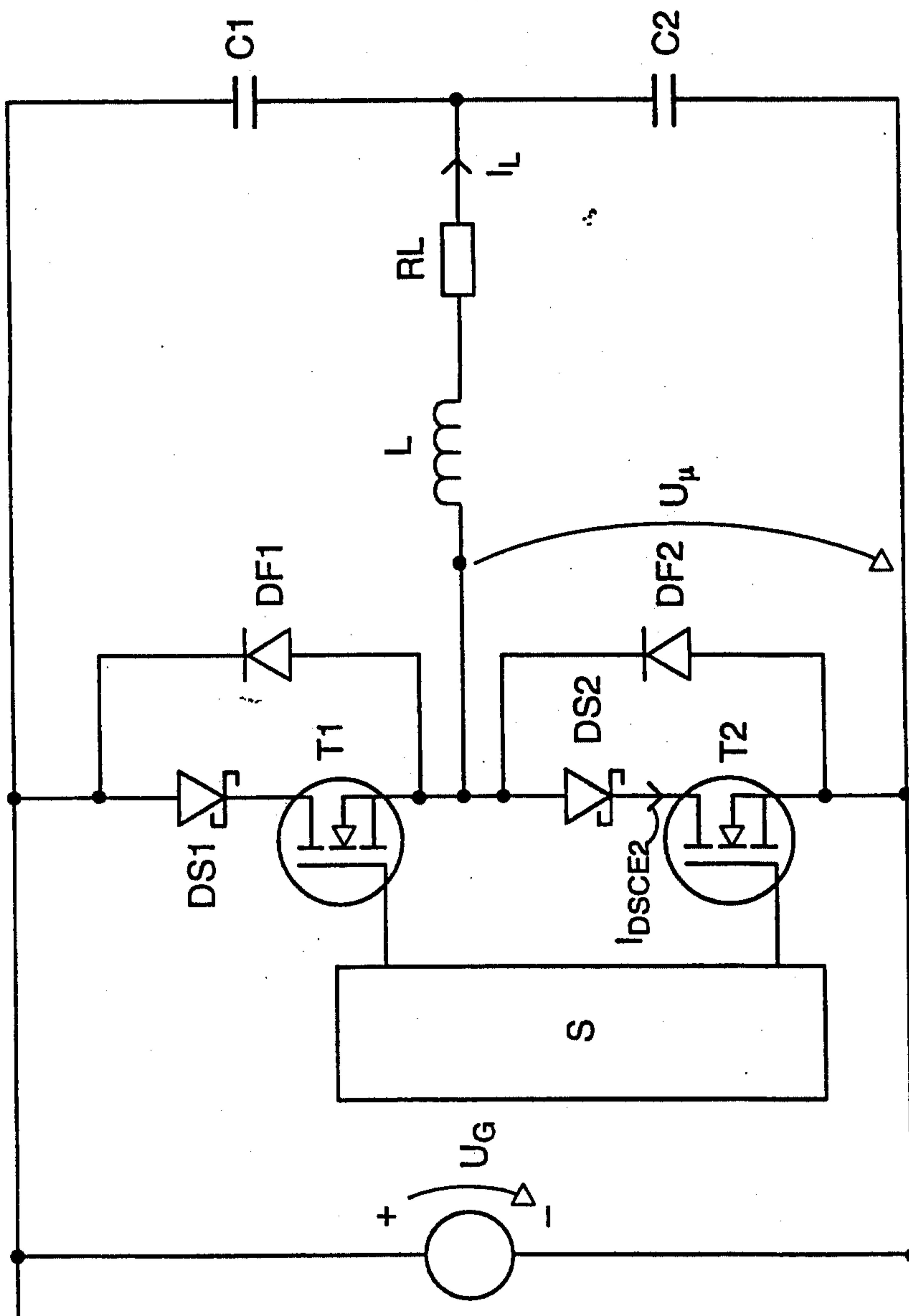


Fig. 1

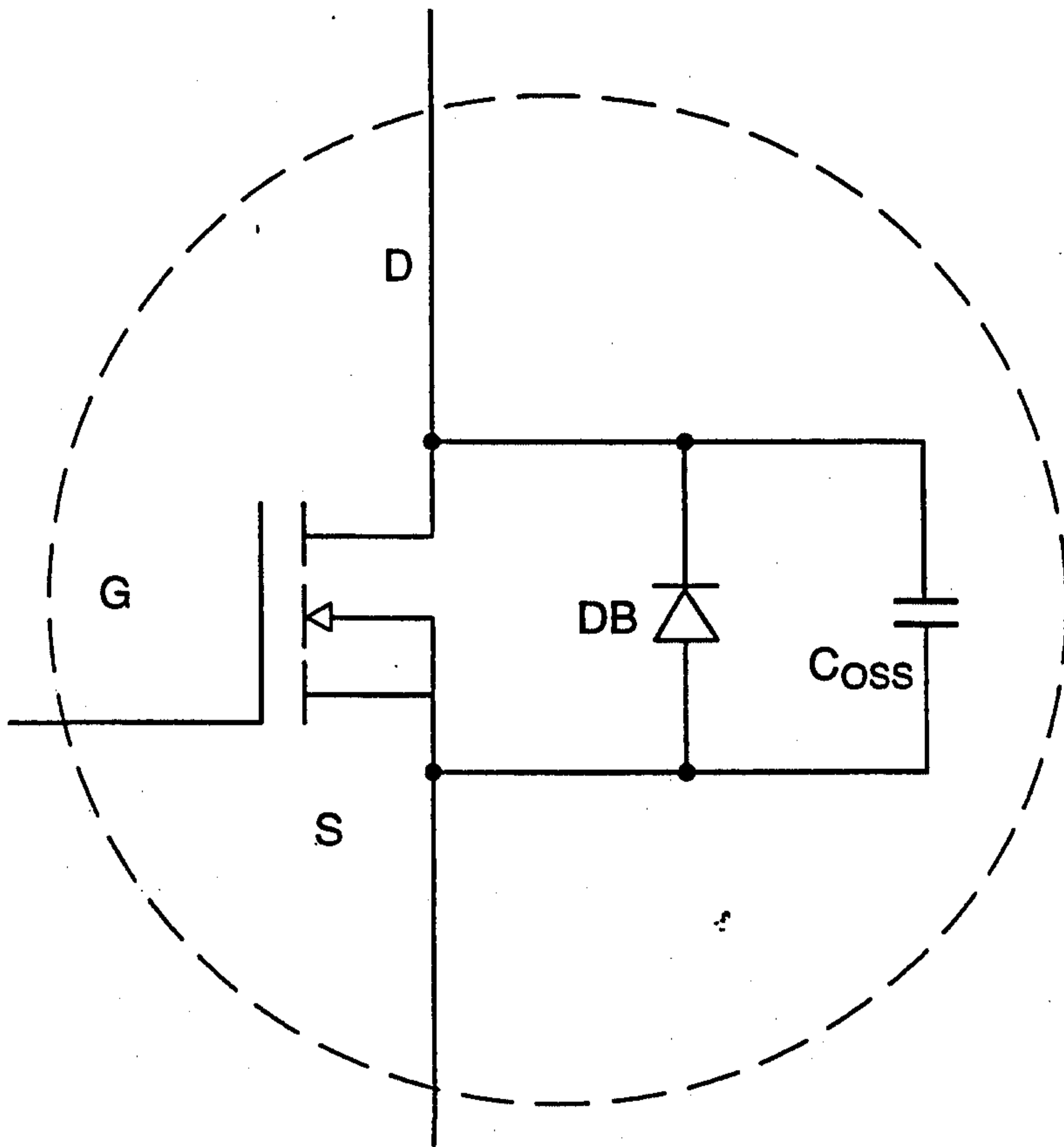


FIG. 2

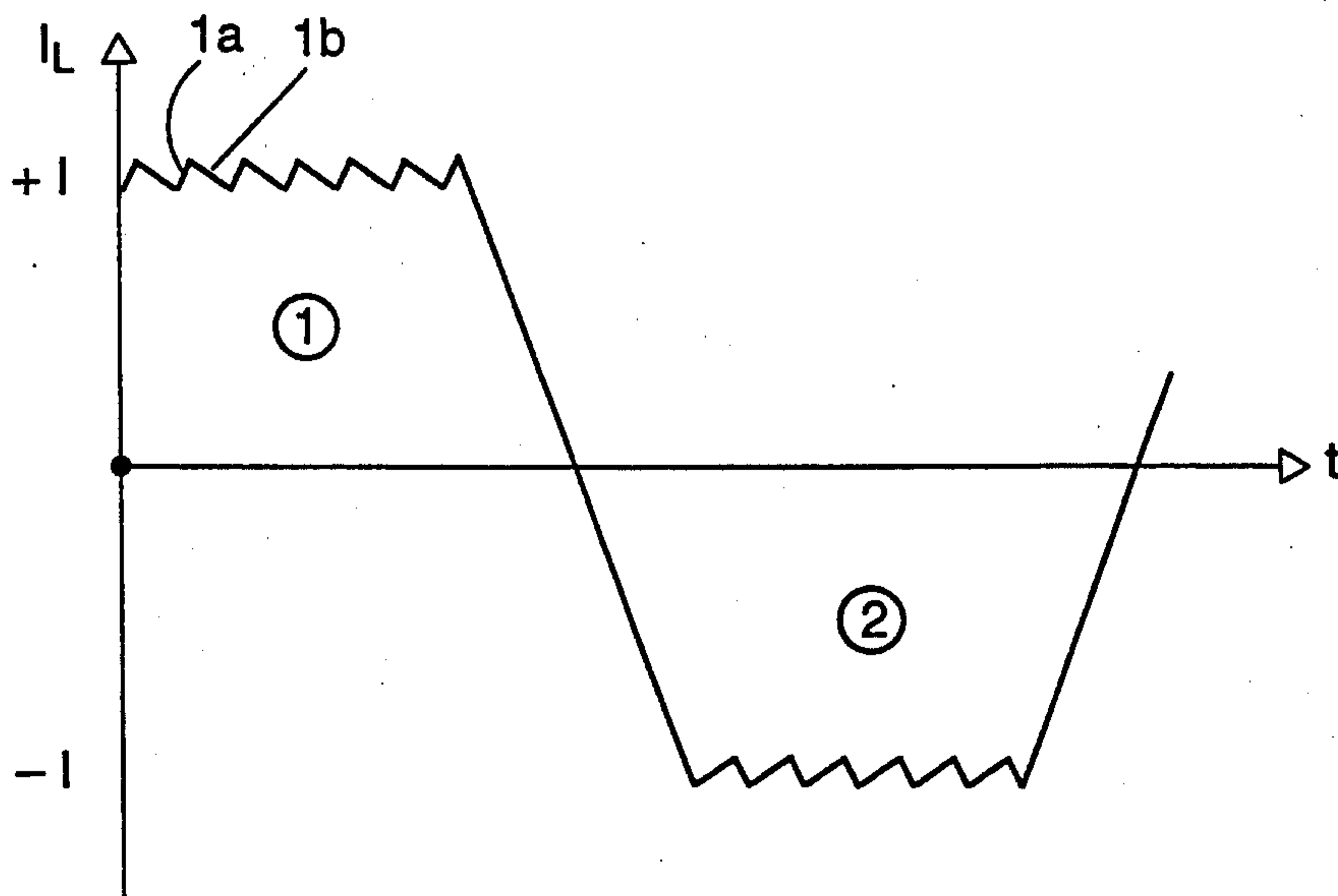


FIG. 3

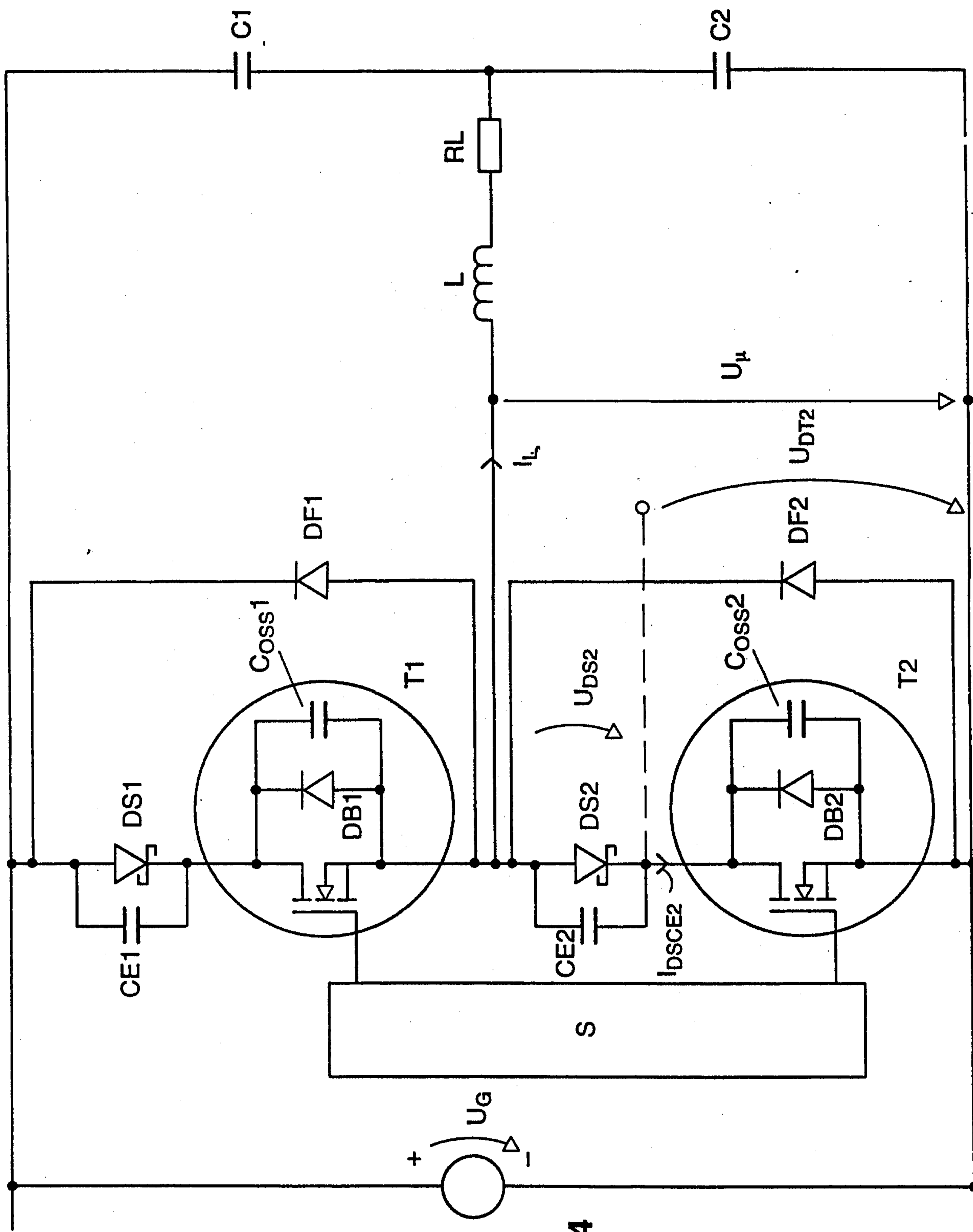


Fig. 4

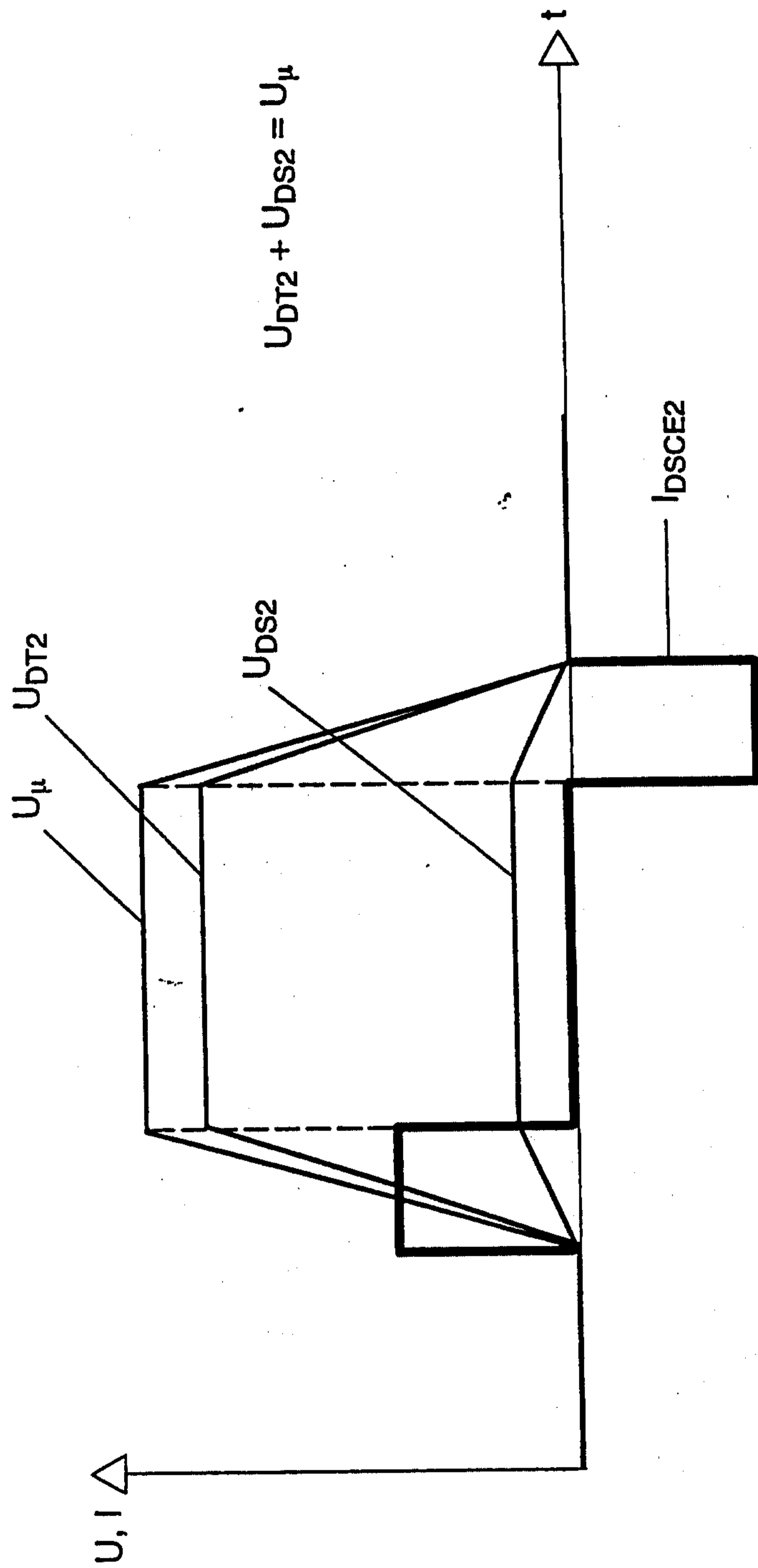


FIG. 5

