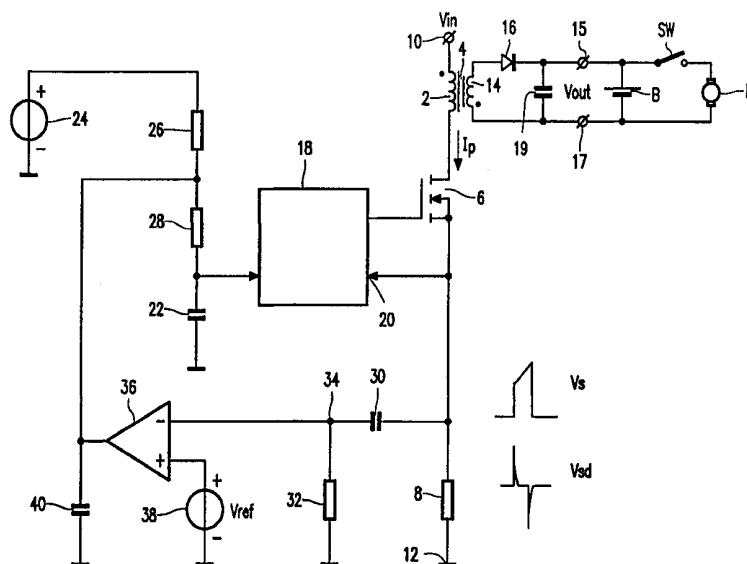




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(54) Title: SWITCHED-MODE POWER SUPPLY WITH CURRENT AND VOLTAGE LIMITATION



(57) Abstract

A switched-mode power supply uses duty cycle control (18) for the switching transistor (6). The primary current through the primary winding (2) is sensed by means of a sensing resistor (8) in series with the switching transistor (6). The voltage across the sensing resistor (8) is differentiated (30, 32), compared (36) with a reference (38) and integrated (40). The integrated signal lengthens the off period of the switching transistor (6), thereby limiting the peak value of the primary current at the beginning of the on period of the switching transistor (6). The peak value of the primary current at the end of the on period is limited by sensing (20) the voltage across the sensing resistor (8). The combined limitations of the primary current ensure that the output current of the switched-mode power supply is limited in a well-defined manner.

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Switched-mode power supply with current and voltage limitation.

The invention relates to a switched-mode power supply, comprising: a series arrangement of a controllable switching element and an inductive element, connected to receive an input voltage, means for rendering the controllable switching element conductive during an on period, so as to produce a current through the series arrangement, which current increases from a minimum value at the beginning of the on period to a maximum value at the end of the on period, and for rendering the controllable switching element non-conductive during an off period.

Such a switched-mode power supply is known from the International Application WO 97/30574. In said known power supply the inductive element is the primary winding of a transformer and the controllable switching element is a switching transistor. The transformer further has a secondary winding which supplies an output current to a battery to be charged and/or another load via a rectifier diode. A problem with this known load is the output current limitation in the event of a short-circuit of the load to be powered. A short-circuit can occur in case of a defect in the load or in the battery to be charged. In rechargeable electrical apparatuses, such as shavers, tooth-brushes, vacuum-cleaners, telephone sets and the like, which are placed in a stand or holder in order to charge the battery, the risk of short-circuit is also substantial because the contact pins of the power supply can inadvertently come into contact with a conductive object. The same can happen if the power supply is incorporated in a mains voltage adapter or power plug which supplies charging current to the rechargeable apparatus. The outlet of the adapter can be short-circuited inadvertently.

A customary method of current-limiting, which is also used in the known power supply, is to limit the maximum value I_{pmax} of the primary current. For this purpose, the primary current is measured and the switching transistor is turned off as soon as the primary current exceeds a certain value. However, in this case the average output current can still run high when the switched-mode power supply starts to operate in the continuous conduction mode, which means that the switching transistor is turned on again before the output current has decreased to zero. The primary current then increases each time from a minimum value I_{pmin} at the beginning of the on period to the maximum value I_{pmax} at the

end of the off period. When the load to be powered is short-circuited the average output current is approximately equal to $n \cdot (I_{pmax} + I_{pmin})/2$, where n is the transformation ratio. Since the output is short-circuited the output current can hardly decrease in value during the off period. In that case the maximum value I_{pmax} is reached almost immediately during the on period, as a result of which the output current rises to approximately $n \cdot I_{pmax}$.

It is an object of the invention to provide a switched-mode power supply having an improved short-circuit behavior. To this end, the switched-mode power supply of the type defined in the opening paragraph is characterized in that the switched-mode power supply further includes means for limiting the minimum value of the current. By limiting the minimum value I_{pmin} it is achieved that the average output current is limited to a value smaller than $n \cdot I_{pmax}$.

To limit the minimum value of the primary current an embodiment of a switched-mode power supply in accordance with the invention is characterized in that the means for limiting include: means for generating a measurement signal having an amplitude which is a measure of the minimum value of the current at the beginning of the on period, means for comparison of the measurement signal with a reference signal, and means for changing the ratio between the on period and the off period in response to the comparison.

At the beginning of the on period, i.e. when the primary current has the minimum value I_{pmin} , the measurement signal is compared with a reference value. On the basis of the comparison the ratio between the on period and the off period is changed, for example by prolonging the off period, in such a manner that the minimum value I_{pmin} does not exceed a given maximum. As a result of this, the output current remains constant when the load is short-circuited.

The magnitude of the minimum value I_{pmin} can be measured by means of a sensing resistor in series with the controllable switching element and a differentiating network which differentiates the voltage across the sensing resistor. The amplitude of the leading edge in the differentiated signal at the beginning of the on period is a measure of the magnitude of the minimum value I_{pmin} . By means of a comparator this amplitude can be compared with a reference signal and can subsequently be averaged. The resulting average comparison signal influences, for example, the off period so as to prolong the off period when the averaged comparison signal increases. The switched-mode power supply then operates so as to maintain the amplitude of the leading edge and, consequently, the magnitude of the minimum value I_{pmin} constant.

The comparator can also be used for limiting the output voltage of the

switched-mode power supply. In the case of an output voltage which is too high the comparator can cause the off period to be extended, as a result of which the power supplied to the load and, consequently, decreases. The output voltage can be determined by measuring the voltage step which occurs across an auxiliary winding or directly across the inductive element during the off period and by adding this voltage step to the differentiated signal, the annoying voltage surge superposed on the voltage step owing to the leakage self-inductance of the inductive element being suppressed by means of the trailing edge of the differentiated signal at the end of the on period.

As a result of its short-circuit characteristics the switched-mode power supply is very suitable for apparatuses using a rechargeable battery, particularly apparatuses having a wall mount or stand in which the power supply is accommodated and which has pins which make contact with the apparatus when it is placed into the stand. The switched-mode power supply is also suitable for use in a mains voltage adapter or power plug which supplies a low voltage to an electrical apparatus with or without a rechargeable battery.

These and other aspects of the invention will be described and elucidated with reference to the accompanying drawings, in which

Figure 1 is a block diagram of a first embodiment of a switched-mode power supply in accordance with the invention;

Figure 2 is a diagram representing the variation of the primary current when a switched-mode power supply in accordance with the invention operates in the discontinuous conduction mode;

Figure 3 is a diagram representing the variation of the primary current when a switched-mode power supply in accordance with the invention operates in the continuous conduction mode;

Figure 4 is a block diagram of a second embodiment of a switched-mode power supply in accordance with the invention;

Figure 5 is a block diagram of a third embodiment of a switched-mode power supply in accordance with the invention;

Figure 6 is a circuit diagram of a fourth embodiment of a switched-mode power supply in accordance with the invention;

Figure 7 is a circuit diagram of a fifth embodiment of a switched-mode power supply in accordance with the invention;

Figure 8 shows an electric shaver including a switched-mode power supply in accordance with the invention;

Figure 9 shows a mains voltage adapter including a switched-mode power supply in accordance with the invention; and

Figure 10 shows a combination of an electric shaver having a rechargeable battery and a stand including a switched-mode power supply in accordance with the invention for charging the battery.

In these Figures parts having a like function or purpose bear the same reference symbols.

Figure 1 shows the block diagram of a switched-mode power supply in accordance with the invention. An inductive element, in the present case a primary winding 2 of a transformer 4, in series with a controllable switching element, in the present case a switching transistor 6, and a sensing resistor 8, is connected between a supply terminal 10 and a ground terminal 12 for receiving an input voltage V_{in} , for example, derived from the rectified mains voltage. The transformer 4 has a secondary winding 14 connected to a load via a rectifier diode 16, which load is shown, by way of example, as a rechargeable battery B and a motor M, which can be arranged in parallel with the battery B by means of a switch SW. The switched-mode power supply, the battery B, the switch SW and the motor M can form part of an electrical apparatus, for example a shaver, having rechargeable batteries which are charged from the mains voltage. The switched-mode power supply can be accommodated in the electrical apparatus itself, in a wall mount or a stand, or in a mains voltage adapter, also referred to as power plug. In the two last-mentioned cases the load is connected to the rectifier diode 16 and the secondary winding 14 via two contacts 15 and 16, across which a capacitor 19 is arranged.

The switching transistor 6 is controlled by a control unit 18, which recurrently turns on the switching transistor 6 for an on period t_1 and subsequently turns off this transistor for an off period t_2 . At the beginning of the on period t_1 the switching transistor 6 is turned on, as a result of which a primary current I_p begins to flow through the primary winding 2, the switching transistor 6 and the sensing resistor 8. The primary current I_p increases to a given maximum value I_{pmax} , as is shown in Figure 2. The rectifier diode 16 is then cut off. The voltage V_s across the sensing resistor 8 then also increases to a maximum value. The voltage V_s is applied to a sensing input 20 of the control unit 18 and as soon as the voltage V_s exceeds the maximum value the control unit 18 turns off the switching transistor 6. This is followed by an off period t_2 whose length is determined by the time required to charge a capacitor 22 to a given voltage from a voltage source 24 via two series-connected resistors 26 and 28. When the voltage across the capacitor 22 exceeds a

given threshold the control unit 18 again turns on the switching transistor 6 and, moreover, the capacitor 22 is discharged. As a result of the interruption of the primary current I_p the sign of the voltage across the secondary winding 14 is reversed. The rectifier diode 16 is now conductive and a decreasing secondary current flows through the load, which current is shown dotted in Figure 2, as a current transformed to the primary side. Upon expiry of the off period t_2 a new cycle begins.

In a manner not shown in Figure 1 the voltage V_{out} across the load is maintained constant by varying the ratio between the on period t_1 and the off period t_2 . When the load increases more power is required, as a result of which the off period t_2 becomes increasingly shorter and the switched-mode power supply begins to operate in the continuous conduction mode, in which, as illustrated in Figure 3, the primary current I_p is already switched on before the secondary current has decreased to zero. In that case the initial value of the primary current I_p is not zero but has a minimum value I_{pmin} when the switching transistor 6 is turned on. During the on period t_1 the primary current I_p increases from the minimum value I_{pmin} to the maximum value I_{pmax} . During the subsequent off period t_2 a decreasing secondary current flows through the load.

In the case of a short-circuit of the load or in the case of overloading the secondary current must be limited in order to prevent the power supply circuit and/or the load from being destroyed. Limiting of the primary current I_p to the value I_{pmax} cannot prevent the average secondary current from rising to a high value when the power supply operates in the continuous conduction mode. When the load is short-circuited the average secondary current is approximately equal to $n \cdot (I_{pmax} + I_{pmin})/2$, where n is the transformation ratio between the primary winding 2 and the secondary winding 14. In the case of a short-circuit the secondary current can hardly decrease during the off period t_2 and the maximum value I_{pmax} is reached almost immediately in the subsequent on period t_1 . As a result, the average secondary current rises to approximately $n \cdot I_{pmax}$.

According to the invention, the secondary current is limited by not only maintaining the maximum value I_{pmax} of the primary current I_p constant but also by preventing the minimum value I_{pmin} of the primary current I_p from exceeding a given value. Thus, in the case of a short-circuit the minimum value I_{pmin} cannot rise to I_{pmax} and the average secondary current is limited to a safe value. The minimum value I_{pmin} can be limited by changing the ratio between the on period t_1 and the off period t_2 in such a manner that the resulting value of I_{pmin} does not exceed the desired value. This can be achieved, for example, by prolonging the off period t_2 .

The minimum value I_{pmin} can be measured by differentiating the voltage across the sensing resistor 8 by means of a differentiating network comprising a capacitor 30 and a resistor 32, which are interconnected in a node 34. In Figure 1 the signal V_s represents the variation of the voltage across the sensing resistor 8 in the continuous conduction mode, while the signal V_{sd} represents the differentiated signal on the node 34. The amplitude of the leading edge in the signal V_{sd} is a measure of the value I_{pmin} . By means of a comparator 36 the signal V_{sd} is compared with a reference voltage V_{ref} supplied by a reference voltage source 38. The output signal of the comparator 36 is averaged by means of a capacitor 40 and is applied to the node between the resistors 26 and 28. The output signal of the comparator 36 thus influences the charging time of the capacitor 22 and hence the length of the off period t_2 . The switched-mode power supply now operates so as to maintain a constant amplitude of the leading edge in the signal V_{sd} . The power supply then functions as a current source with a limited average secondary current.

The comparator 36 can also be used for limiting the output voltage V_{out} across the load. In the case that the output voltage is too high the comparator 36 can cause the off period to be prolonged, as a result of which the power delivered to the load and, consequently, the output voltage V_{out} decreases. Figure 4 shows an embodiment in which the voltage V_{out} is measured by means of an auxiliary winding 42. During the off period t_2 a signal voltage V_a , which is a measure of the output voltage V_{out} , appears across the auxiliary winding 42. The signal voltage V_a is applied to the node 34 via a diode 44 and a resistor 46 and is compared with the reference voltage V_{ref} by means of the comparator 36. The leakage inductance of the transformer 4 produces a large voltage transient in the signal V_a upon turn-off of the switching transistor 6, but this transient is suppressed by the negative trailing edge in the signal V_{sd} , which also appears on the node 34. The diode 44 isolates the node 34 from the auxiliary winding 42 during the on period t_1 and also compensates for the voltage drop across the rectifier diode 16.

Figure 5 shows a variant in which the voltage V_{out} is measured directly across the primary winding 2. The node between the switching transistor 6 and the primary winding 2 is connected to the emitter of a PNP transistor 50 via a resistor 48, which transistor has its base connected to the node between two resistors 52 and 54, arranged in series between the supply terminal 10 and the voltage source 24, and has its collector connected to the node 34. The emitter of the transistor 50 is also connected to the voltage source 24 via a resistor 49. In the off period t_2 the voltage on the node between the switching transistor 6 and the primary winding 2 is higher than the voltage V_{in} . The voltage

dividers comprising the resistors 52 and 54 and the resistors 48 and 49 have been dimensioned in such a manner that the base-emitter junction of the transistor 50 then becomes conductive. This drive of the transistor 50 operates independently of the input voltage V_{in} . Now a current flows through the transistor 50, whose magnitude is mainly
5 determined by the value of the resistor 48. This current also flows through the resistor 32, where it produces a signal voltage having the same waveform as the signal V_a in Figure 4. In the present case the transient voltage is again suppressed by the negative trailing edge in the signal V_{sd} across the resistor 32.

The power supply circuits in Figures 4 and 5 are both current-limited and
10 voltage-limited. The voltage V_{out} never exceeds a predetermined value. In addition, the average value of the secondary current and, as a consequence, the current supplied to the load is limited. This makes the power supply circuit very suitable as a battery charger.

Figure 6 is a detailed circuit diagram of a switched-mode power supply with a current and voltage limitation in accordance with the block diagram of Figure 5. The
15 a.c. mains voltage or a suitable direct voltage is applied to input terminals 60 and 62. If desired, the a.c. mains voltage can be applied via a transformer (not shown). The a.c. mains voltage is rectified by means of a diode bridge 64 and is smoothed and filtered by means of capacitors 66 and 68 and a coil 70. It is also possible to use a single rectifier diode instead of a diode bridge. An optional resistor 72 limits the current through the diode bridge 64. The
20 negative terminal of the rectified input voltage is connected to the ground terminal 12. The positive terminal 10 is connected to the primary winding 2 of the transformer 4. A zener diode 74 and a diode 76 are arranged in parallel with the primary winding 2 and limit the voltage across the primary winding 2 when the current through the primary winding 2 is interrupted. Instead of the zener diode 74 and the diode 76 shown here, alternative circuits,
25 for example a series arrangement of a capacitor and a resistor, can be used in order to define the variation of the voltage across the primary winding 2.

The voltage source 24 of Figure 5 is implemented by means of a zener diode 78 and a capacitor 80 between a node 82 and the ground terminal 12. The node 82 is connected to the positive terminal 10 via the resistors 52 and 54.

30 The control unit 18 is constructed as a discrete monostable multivibrator which drives the switching transistor 6 on its source electrode. The switching transistor 6 has its gate connected to the node 82 via a resistor 84 in order to suppress possible turn-off transients of the switching transistor 6. The switching transistor 6 has its source connected to the emitter of a PNP transistor 86 whose collector is connected to the ground terminal 12 via

the sensing resistor. The sensing resistor has been split into two resistors 88 and 90, the resistor 88 being connected to the collector of the transistor 86 and the resistor 90 being connected to the ground terminal 12. The resistors 88 and 90 are connected to one another in a tapping point. An NPN transistor 92 has its emitter connected to this tapping point and has its collector connected to the base of the transistor 86. The timing of the monostable multivibrator is determined by the resistors 26 and 28 and a timing capacitor 94. The resistors 26 and 28 are connected in series between the node 82 and the base of the transistor 92. The timing capacitor 94 is connected between the base of the transistor 92 and the node between the resistor 88 and the collector of the transistor 86. A zener diode 96 is connected between the base of the transistor 92 and the ground terminal 12. The zener diode 96 breaks down if the voltage on the base of the transistor 92 exceeds a given threshold and then forms a low-impedance current path to the ground terminal 12. A resistor 98 is connected in parallel with the base-emitter junction of the transistor 86. A capacitor 100 across the resistor 88 suppresses parasitic oscillations.

The comparator 36 of Figure 5 comprises an NPN transistor 102, which has its base connected to the node 34, its emitter to the ground terminal 12 and its collector to the node between the resistors 26 and 28, which node is also connected to the capacitor 40 which averages the output signal of the transistor 102. The base-emitter junction voltage V_{be} of the transistor 102 functions as the reference voltage V_{ref} . The capacitor 30 of the differentiating network is connected to the node between the resistors 88 and 90.

The transistor 92 is turned on as soon as the timing capacitor 94 has been charged positively via the resistors 26 and 28 to approximately +0.6 V. The transistor 92 then drives the transistor 86 and the switching transistor 6 into conduction. The increasing current through the switching transistor 6 and the transistor 86 produces an increasing voltage across the resistor 88, which voltage is fed back to the base of the transistor 92 via the timing capacitor 94. The timing capacitor 94 provides positive feedback in that a current begins to flow via the timing capacitor 94 to the base of the transistor 92. As a result of this, the timing capacitor is charged negatively. The transistor 92 remains in the on state until the voltage across the resistor 90 has become equal to the zener voltage of the zener diode 96.

From this instant the current through the timing capacitor 94 flows via the zener diode 96 instead of to the base of the transistor 92. The transistor 92 and, consequently, the transistor 86 as well as the switching transistor 6 will then be turned off. When the switching transistor 6 is turned off the voltage across the resistors 88 and 90 ceases. Since the timing capacitor 94 has been charged negatively the transistors 92 and 86 and, consequently, also the

switching transistor 6, remain non-conductive until the capacitor 94 has been re-charged positively via the resistors 26 and 28.

If the peak voltage on the node 34 is higher than the V_{be} of the transistor 102 the transistor 102 is turned on and pulls the voltage on the capacitor 40 towards a smaller value, as a result of which it takes longer for the timing capacitor 94 to be charged positively. Thus, the off period is extended if the primary current I_p exceeds a given threshold when the switching transistor 6 is turned on.

The resistor 98 contributes to a better defined turn-on instant of the transistor 86. The collector current of the transistor 92 must first build up a threshold voltage across the resistor 98 before the transistor 86 can be turned on. The transistors 50, 86, 92 and 102 can be constructed alternatively as MOS transistors, if desired.

Figure 7 shows an embodiment based on a switcher IC type TOP210 which is commercially available from Power Integrations, Inc. The switcher IC 104 has a terminal DRN ("DRAIN") to which the primary winding 2 is connected, a terminal SRC ("SOURCE"), which is connected to the ground terminal 12 via the sensing resistor 8, and a terminal CTL ("CONTROL"), which is connected to a first terminal of an auxiliary winding 110 of the transformer 4 via a resistor 106 and a diode 108, which auxiliary winding has its other terminal connected to the terminal SRC of the switcher IC 104. The switcher IC controls the output voltage in a manner similar to that described with reference to Figure 4. A voltage comparable to the signal voltage V_a in Figure 4 appears across the auxiliary winding 110. This voltage is stored in a capacitor 112 connected between the terminals CTL and SRC. The switcher IC 104 controls the duty cycle in response to the current applied to the terminal CTL. In addition to the output voltage control there is provided current-limiting control. The differentiation of the primary current is effected by means of the sensing resistor 8 and a network similar to that of Figure 4. In the same way as in Figure 6, the comparator with the associated integrating capacitor comprises the transistor 102 and the capacitor 40. A series arrangement of a capacitor 114 and diode 116 is arranged in parallel with the auxiliary winding 110. The node between the capacitor 114 and the diode 116 is connected to the terminal CTL via a diode 118 and the emitter-collector path of a transistor 120. The base of the transistor 120 is connected to the capacitor 40 by means of a resistor 122. The capacitor 114 and the diodes 116 and 118 form a charge-transfer device which is turned on by means of the transistors 102 and 120. When the transistor 120 is turned on extra current is supplied to the terminal CTL, as a result of which the output current is limited.

The power supply circuit in accordance with the invention is suitable for electrical apparatuses having rechargeable batteries, for example NiCd or NiMH batteries, which are charged from the mains voltage. Figure 8 shows, by way of example, an electric shaver having a housing H, which accommodates the power supply circuit, referenced PS, the rechargeable battery B and the motor M. The motor drives the shaving heads SH and is activated by means of the switch SW.

Figure 9 shows a mains voltage adapter or power plug PP including the power supply circuit PS. The power plug PP is adapted to cooperate with the shaver of Figure 8, in which case the shaver accommodates the rechargeable battery B but does not include the power supply circuit PS.

Figure 10 shows a combination of a shaver whose housing H is placed in a compartment CM of a stand ST. The stand accommodates the power supply circuit PS which charges the battery B, which is accommodated in the housing H of the shaver, via contacts (not shown) in the compartment CM.

It will be evident that the power supply circuit is also suitable for other electrical apparatuses, with or without rechargeable batteries, such as electric toothbrushes, drills, vacuum-cleaners and the like.

CLAIMS:

1. A switched-mode power supply, comprising: a series arrangement of a controllable switching element (6) and an inductive element (2), connected to receive an input voltage (V_{in}), means (18) for rendering the controllable switching element (6) conductive during an on period, so as to produce a current (I_p) through the series arrangement, which current increases from a minimum value at the beginning of the on period to a maximum value at the end of the on period, and for rendering the controllable switching element (6) non-conductive during an off period, characterized in that the switched-mode power supply further includes means (8, 30, 32, 36) for limiting the minimum value of the current.

10

2. A switched-mode power supply as claimed in Claim 1, characterized in that the means for limiting include: means (8) for generating a measurement signal having an amplitude which is a measure of the minimum value of the current at the beginning of the on period, means (36) for comparison of the measurement signal with a reference signal, and means (26, 28, 22, 18) for changing the ratio between the on period and the off period in response to the comparison.

3. A switched-mode power supply as claimed in Claim 2, characterized in that the means for generating the measurement signal include: a sensing resistor (8) in series with the controllable switching element (6) and a differentiating network (30, 32) for supplying the measurement signal by differentiation of a signal voltage across the sensing resistor (8).

4. A switched-mode power supply as claimed in Claim 2 or 3, characterized in that the means for comparison include: a comparator (36) having inputs for receiving the reference signal and the measurement signal and having an output for supplying a comparison signal, and means (40) for averaging the comparison signal and for supplying an averaged comparison signal.

5. A switched-mode power supply as claimed in Claim 4, characterized in that the means for changing (26, 28, 22, 18) prolong the off period in response to the averaged comparison signal.

5 6. A switched-mode power supply as claimed in Claim 3, 4 or 5, characterized in that the switched-mode power supply further includes: means (42) for generating a further measurement signal which is a measure of a voltage across a load to be powered, and means (44, 46) for adding the further measurement signal to the first-mentioned measurement signal.

10 7. A switched-mode power supply as claimed in Claim 6, characterized in that the means for generating a further measurement signal include: an auxiliary winding (42), magnetically coupled to the inductive element (2), and the means for adding comprise a diode (44) for coupling a voltage across the auxiliary winding (42) to the first-mentioned
15 measurement signal during the off period.

8. A switched-mode power supply as claimed in Claim 6, characterized in that the means for generating a further measurement signal comprise the inductive element (2), and the means for adding comprise: a first voltage divider (48, 49) connected between a
20 reference terminal (24) and a node between the inductive element (2) and the controllable switching element (6), a second voltage divider (52, 54) connected between a terminal (10) for receiving the input voltage and the reference terminal (24), a transistor (50) having a first main electrode connected to a tapping point of the first voltage divider (48, 49), having a second main electrode coupled to an output (34) of the differentiating network, and having a
25 control electrode connected to a tapping point of the second voltage divider (52, 54).

9. An electric shaver (H) comprising: a rechargeable battery (B), an electrical load (M), a switch (SW) for connecting the load (M) to the battery (B), and a switched-mode power supply (PS) as claimed in any one of the preceding Claims, for
30 supplying power to at least the battery (B) and/or the load (M).

10. An electric shaving system comprising: a shaver including a rechargeable battery (B), an electrical load (M), a switch (SW) for connecting the load (M) to the battery (B), and a stand (ST) including a switched-mode power supply (PS) as claimed in any one of
35 the preceding Claims, for supplying power to at least the battery (B) and/or the load (M).

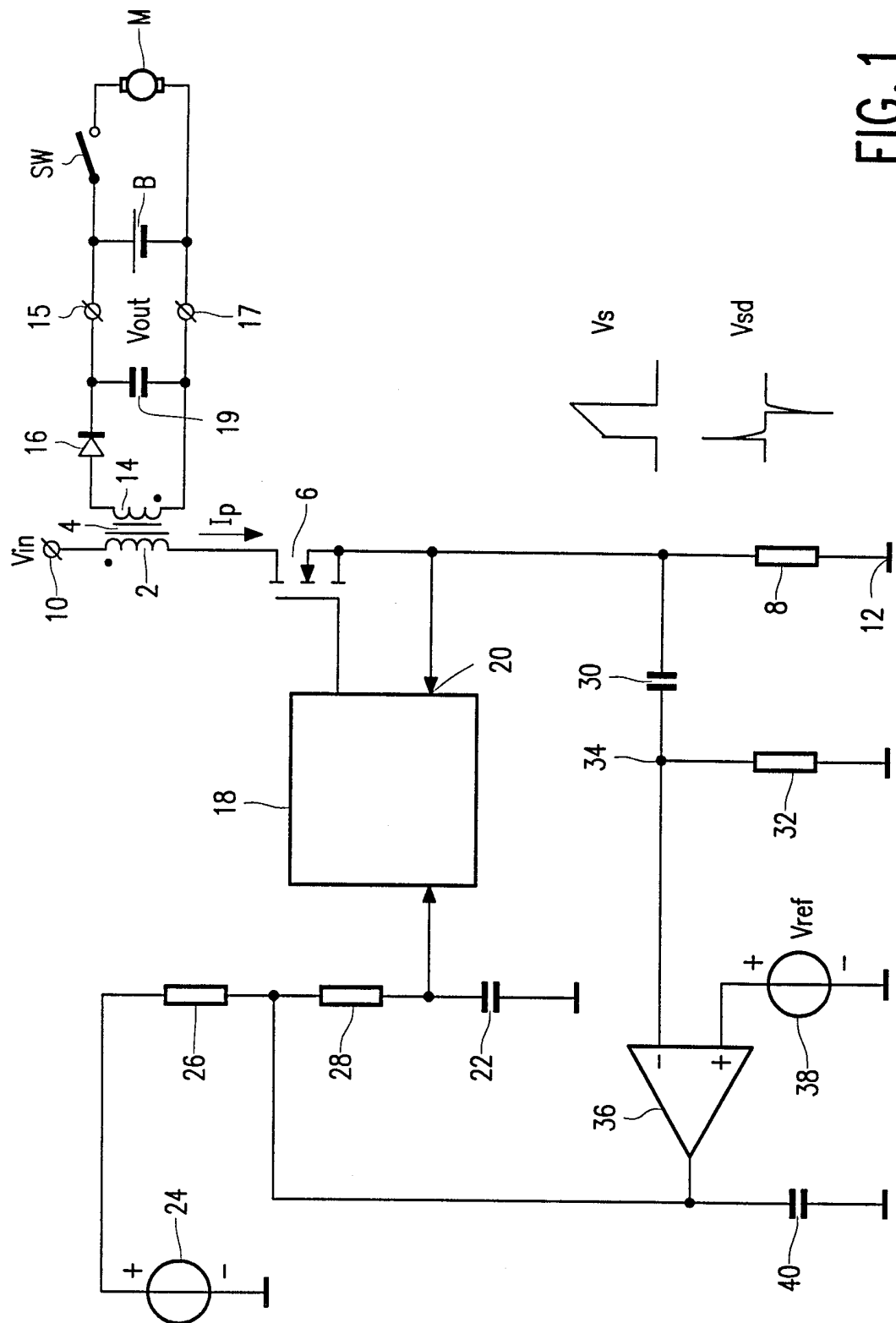
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FIG. 1

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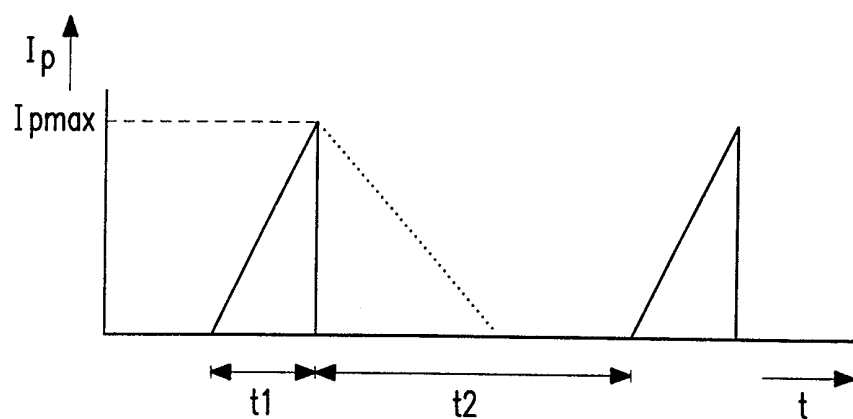


FIG. 2

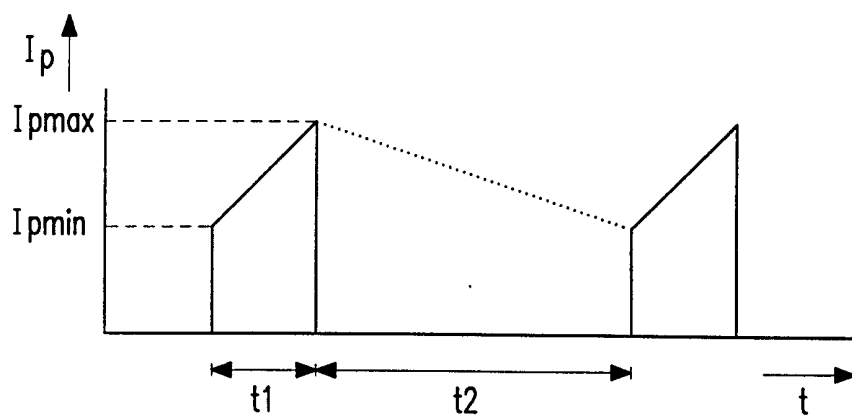
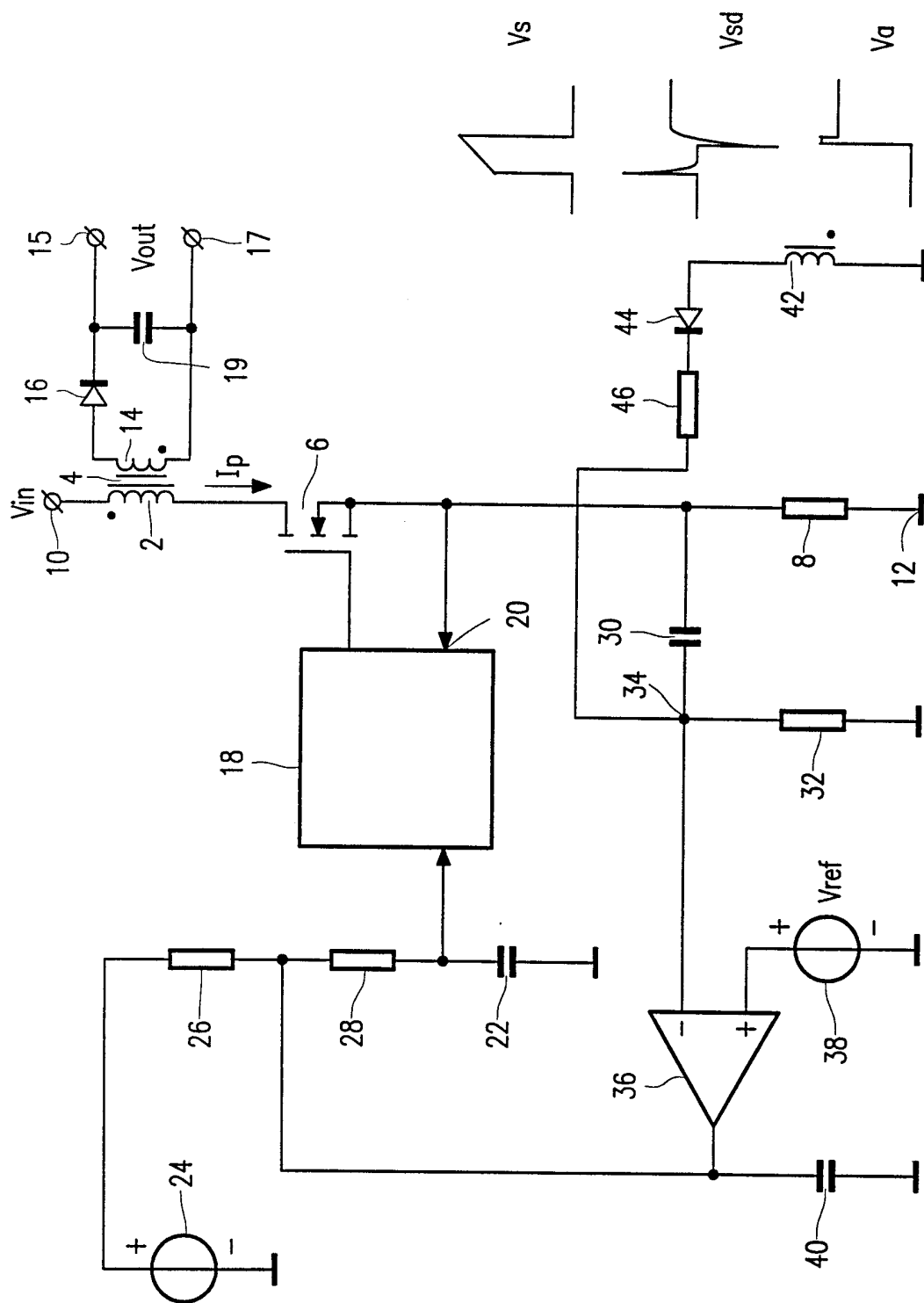


FIG. 3

FIG. 4



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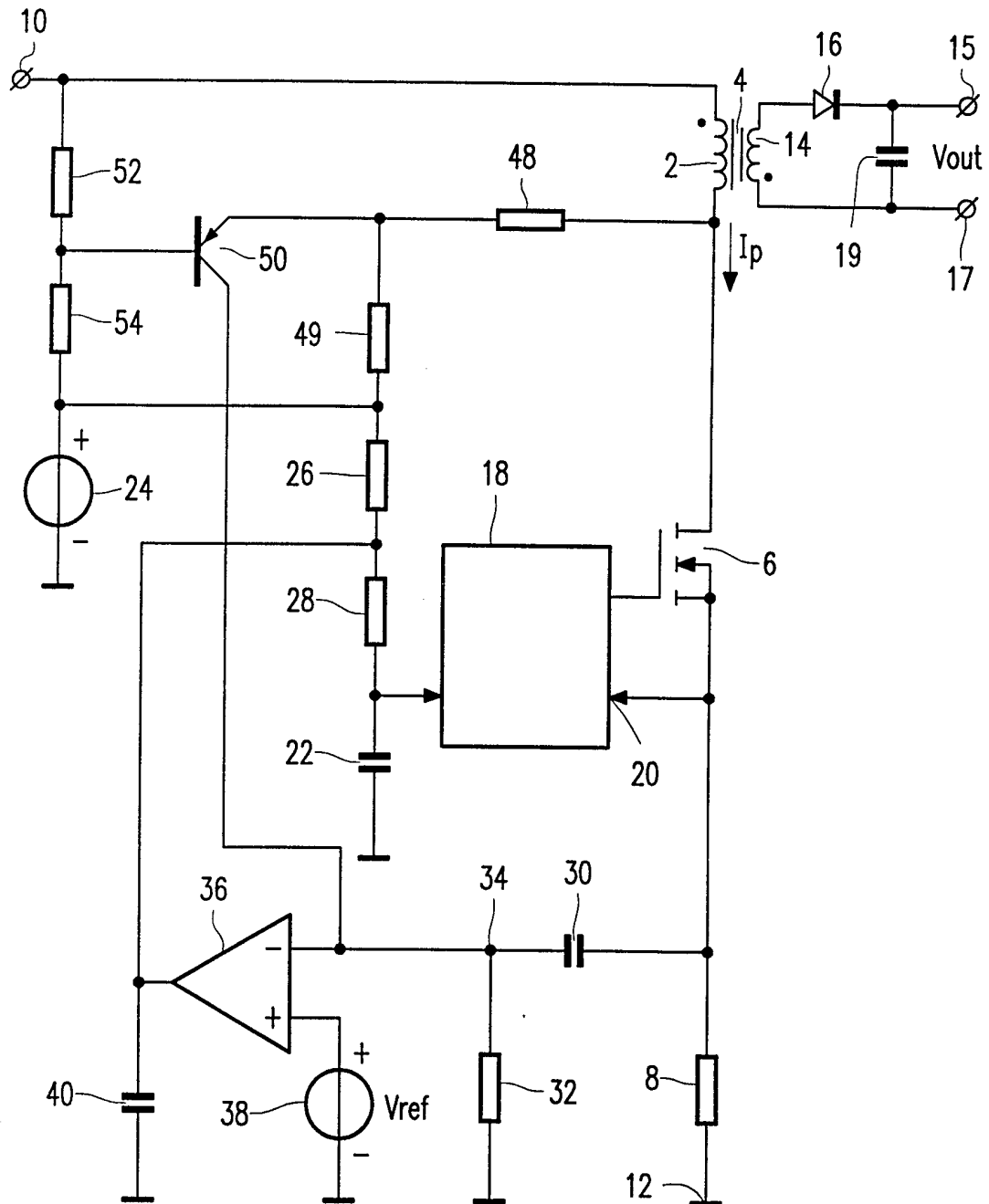


FIG. 5

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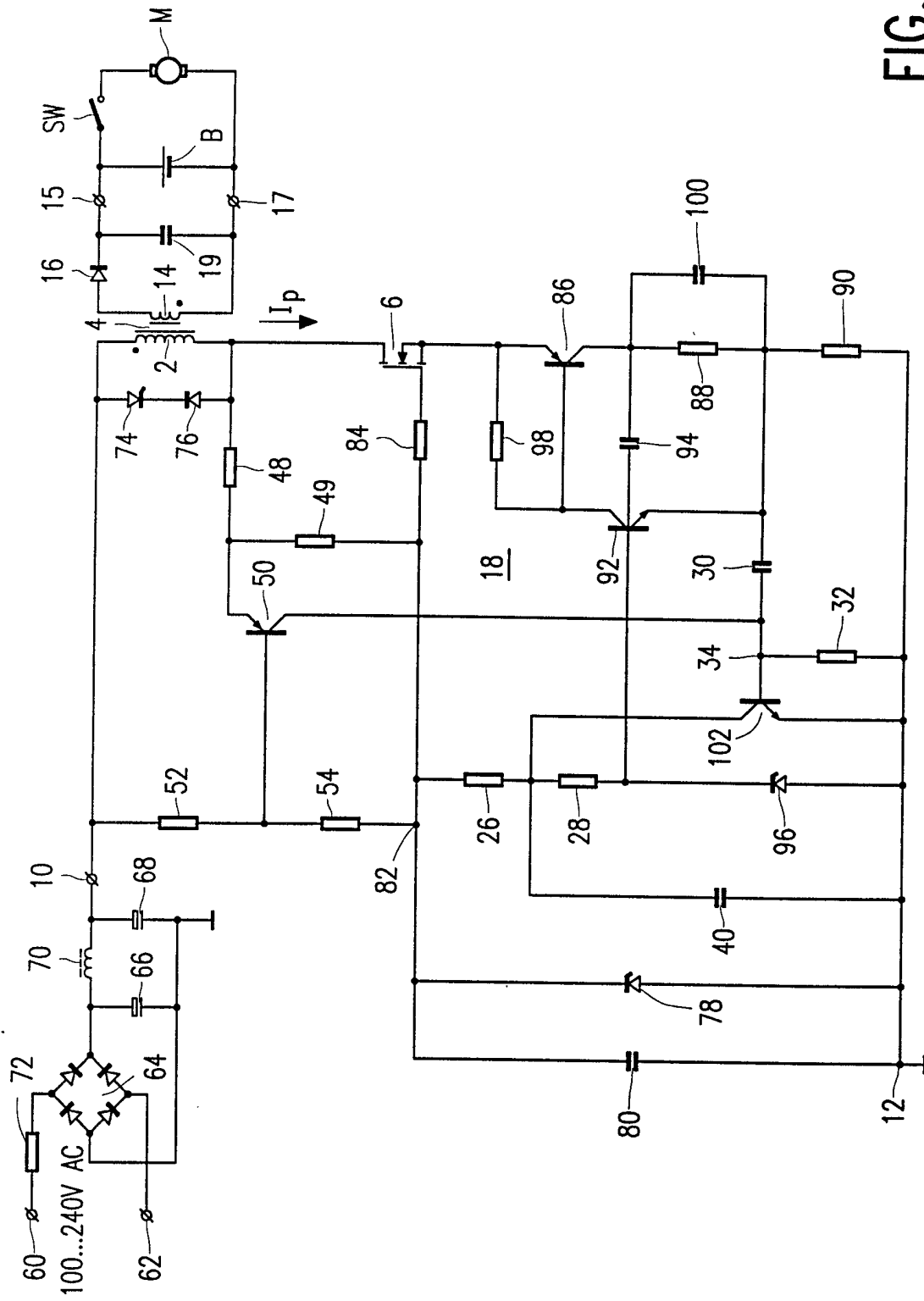


FIG. 6

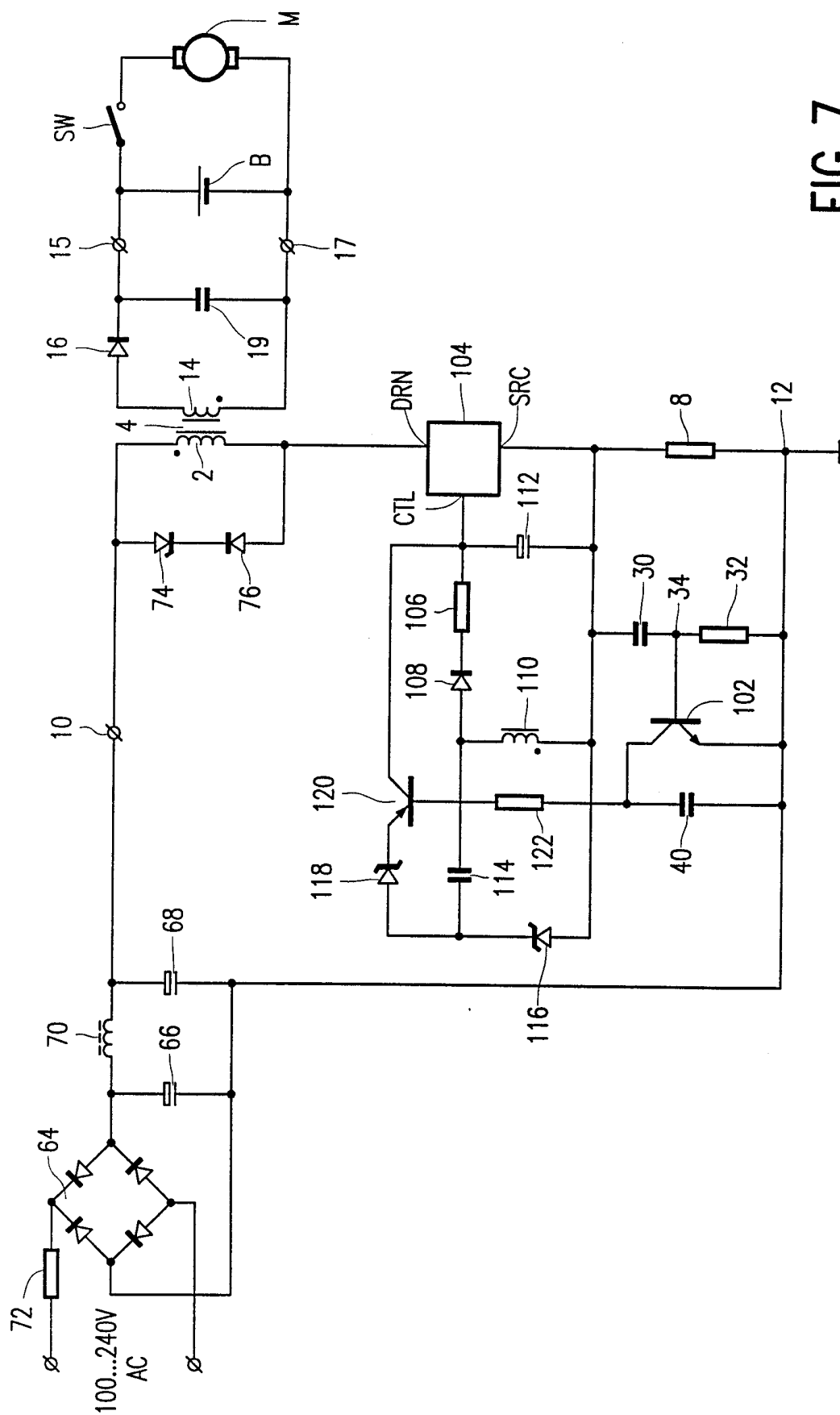


FIG. 7

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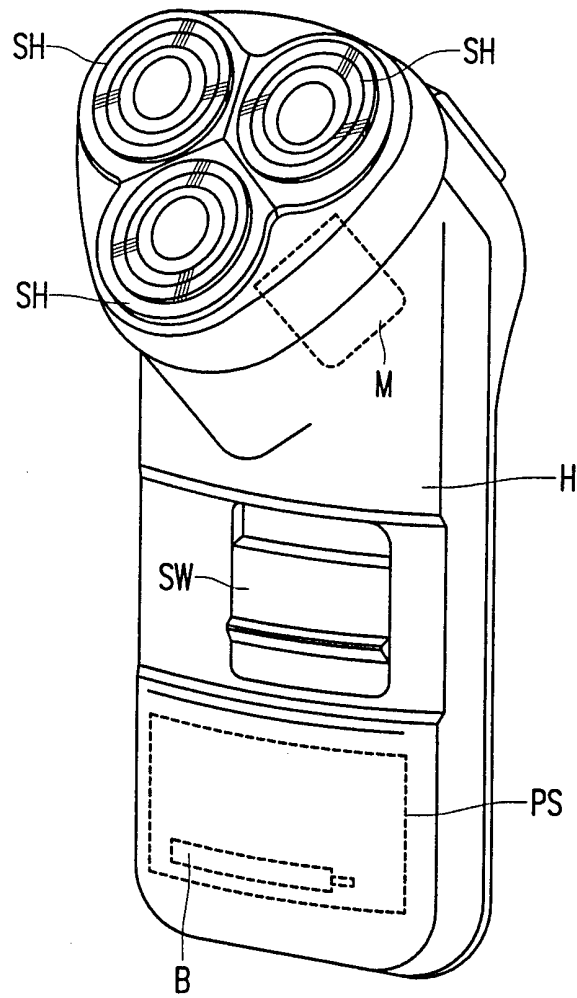


FIG. 8

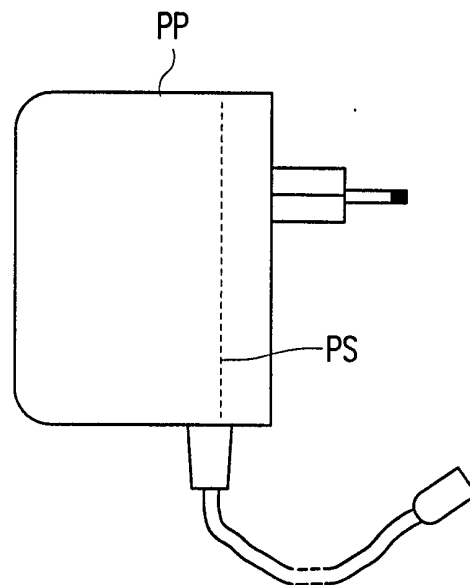


FIG. 9

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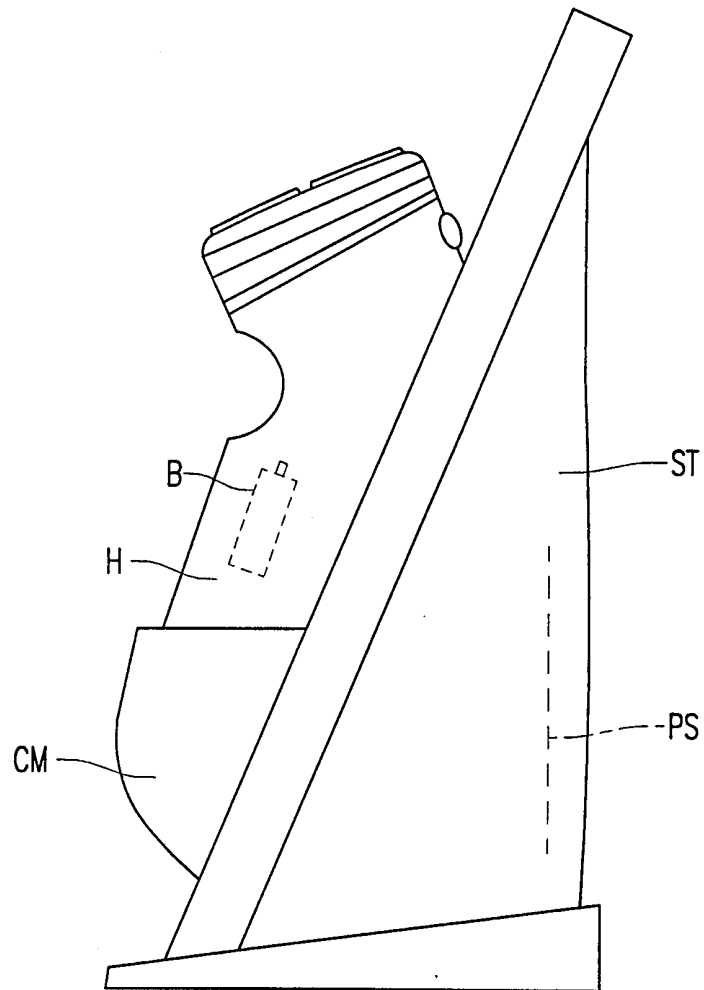


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB 98/01892

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02M 3/335, H02M 7/217

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H02M, H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, TXTUS1, TXTUS2, TXTGB1, TXTEP1, TXTW01

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4928200 A (REDL ET AL.), 22 May 1990 (22.05.90), column 3, line 8 - column 4, line 21, figure 2 --	1-10
D,A	WO 9730574 A1 (PHILIPS ELECTRONICS N.V. ET AL.), 28 August 1997 (28.08.97), abstract --	1-10
A	WO 8504059 A1 (HUGHES AIRCRAFT COMPANY), 12 Sept 1985 (12.09.85), figure 2, abstract -- -----	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search

23 April 1999

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Name and mailing address of the ISA/

Swedish Patent Office

Box 5055, S-102 42 STOCKHOLM

Facsimile No. +46 8 666 02 86

Authorized officer

Tomas Erlandsson

Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/03/99

International application No.

PCT/IB 98/01892

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
US	4928200	A	22/05/90	US	4819122	A	04/04/89
WO	9730574	A1	28/08/97	EP	0835547	A	15/04/98
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WO	8504059	A1	12/09/85	CA	1245284	A	22/11/88
				DE	3566335	A	22/12/88
				EP	0173697	A,B	12/03/86
				SE	0173697	T3	
				JP	6055031	B	20/07/94
				JP	61501605	T	31/07/86
				US	4612610	A	16/09/86