(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 175 724 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
22.03.2006 Bulletin 2006/12

(21) Application number: **01905591.2**

(22) Date of filing: **30.01.2001**

(51) Int Cl.:
H02M 3/155 $^{(2006.01)}$ *H02M 3/10* $^{(2006.01)}$

(86) International application number:
PCT/CN2001/000103

(87) International publication number:
WO 2001/059917 (16.08.2001 Gazette 2001/33)

(54) POWER CONVERTER

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CONVERTISSEUR DE PUISSANCE

(84) Designated Contracting States:
DE FR GB IT

(30) Priority: **07.02.2000 US 499836**

(43) Date of publication of application:
30.01.2002 Bulletin 2002/05

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- **PATENT ABSTRACTS OF JAPAN vol. 016, no. 074 (E-1170), 24 February 1992 (1992-02-24) & JP 03 265465 A (YOKOGAWA ELECTRIC CORP), 26 November 1991 (1991-11-26)**
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Printed by Jouve, 75001 PARIS (FR)

Description

FIELD OF THE INVENTION

[0001] The present invention relates to the field of switch mode power converters.

BACKGROUND OF THE INVENTION

[0002] Switching converter topologies are widely used as the major building block in high efficiency and lightweight power supplies such as those used in computer applications. A major shortcoming of switching converters, however, is its transient output response to a fast load change. Because most switching power converters include an output inductor, a switching power converter's transient response is inherently limited. For example, a typical buck converter comprises a power stage having a plurality of switches and an inductor-capacitor filter, and a feedback circuit. The feedback circuit monitors the converter output voltage and exerts pulse width modulation control over the switches. When there is a fast dynamic load change, the converter's ability to respond is limited by the feedback circuit and the power stage. The feedback circuits can be designed to respond quicker through traditional linear or non-linear approaches. The inherent response of the converter, however, is limited by the power stage and, in particular, the output inductor.

[0003] Some have attempted to improve upon the power converter's dynamic response by using an inductor with a small inductance value. This technique does improve the power converter's dynamic response because current flow can change much more quickly when a small indicator is used. This technique, however, is disadvantaged in that the use of a small inductor results in a ripple current during normal operation. High ripple current introduces high root mean square current in the converter switches and passive components and, as a result, increases the power loss.

[0004] Others have attempted to reduce power losses by using parallel switches to share the current, but this method increases the cost and complexity of the converters. Still others have attempted to improve upon the converter's transient response by increasing the converter's switching frequency. This technique is disadvantaged in that it induces excessive switching losses in the switches and excessive magnetic losses in the inductor core. Moreover, high frequency operation requires the use of high performance drive circuit which can further escalate the converter's cost.

[0005] Therefore, there remains a need for a method of providing a switching power converter with a fast transient response while minimizing the converter's power loss.

[0006] Document US 4 447 866 teaches the use of a saturable core reactor and error amplifier to achieve post-regulation of an output voltage of a dc-to-dc converter. The conventional regulation of the output voltage, such as cross-regulation, is supplemented by actively controlling the inductance of a saturable core inductor. The voltage drop across the saturable core inductor is a function of the current flowing in a control winding magnetically coupled to the saturable core inductor. An error amplifier detects changes in the level of output of the output voltage and causes compensating changes in the current flowing through the control winding, so as to affect the voltage drop across saturable core inductor in a manner to obtain a constant output voltage.

[0007] Document DE 32 09 975 A1 also discloses a dc-to-dc converter having a saturable core inductor. This is connected in series with the secondary winding of a transformer and its inductance state is controlled by a control circuit which also senses the voltage at the output of the converter. The control circuit conducts the saturable core inductor into saturation if the output voltage is lower than a reference voltage. In consequence, the impedance of the saturable core inductor is decreased and the output voltage of the converter raises. If the output voltage exceeds the reference voltage, the control circuit drives the saturable core inductor out of saturation, thereby increasing its impedance and voltage drop. As a result, the output voltage of the converter is lowered.

[0008] Document JP 03 265465 shows a voltage resonance switching power supply having a variable inductor connected in series with the primary winding of a transformer This series connection is supplied with a chopped voltage output by two semiconductor switches. The voltage output at the secondary winding of the transformer is rectified, smoothed through an inductor and a capacitor and applied to a load. To maintain the output voltage of the power supply constant, the inductance of the variable inductor is varied by means of a control circuit that controls the current through the variable inductor in response to a deviation of the output voltage from a reference voltage.

SUMMARY OF THE INVENTION

[0009] To improve upon the foregoing technology as disclosed in the current state-of-the-art, the present invention discloses an apparatus and method for improving the transient response of switching power converters. The present invention dramatically increases the rate of change of current through the converter's output inductor by causing the output inductor to enter a lower inductance state during transients while maintaining low current ripple at normal load by keeping the output inductor at a higher inductance state during steady state conditions.

[0010] This is achieved by the features as set forth in claim 1. Further advantageous embodiments of the present invention are set forth in the dependent claims.

[0011] The present invention provides many advantages over the presently known power conversion topologies. Not all of these advantages are simultaneously required to practice the invention as claimed, and the following list is merely illustrative of the types of benefits that may be provided, alone or in combination, by the present invention. These advantages include: (1)fast dynamic response; (2) low output inductor ripple current; (3) increased power efficiency; (4) lack of a need to operate at a high switching frequency; (5) adjustability to the load demands; (6) non-complex control method; and (7) applicability to most power converter topologies.

[0012] A power conversion topology is provided that includes input means for receiving input power, an output for providing regulated output power, and a variable inductance device coupled between the input means and the output. The variable inductance device has both a higher inductance state and a lower inductance state. The variable inductance device is controllable to switch between the higher inductance state and the lower inductance state. In one embodiment, the power converter further includes a control circuit that is operable to signal the variable inductance device to switch from one of the inductance states to the other inductance state.

[0013] The variable inductance device,in one embodiment, comprises a fixed component and a variable component in series with the fixed component. The variable inductance component optionally comprises a transformer having a plurality of windings magnetically coupled to each other wherein a first winding is coupled in series with the fixed inductance component. A second and third winding are each optionally coupled in series with a power source and a switch wherein the application of the power source to one of the second or third windings through the use of the switches has the effect of reducing the effective inductance of the variable inductance component.

[0014] In another embodiment, the variable inductance device comprises a lower inductance element, a switch coupled in series with the lower inductance element thereby forming a switch and lower inductance element series combination, and a higher inductance element coupled in parallel with the switch and lower inductance element series combination. The switch is operable to switch the variable inductance device between the lower inductance state and the higher inductance state by coupling or decoupling the lower inductance element in parallel to the higher inductance element.

BRIEF DESCRIPTION OF DRAWINGS

[0015] The present invention will become more apparent from the following description when read in conjunction with the accompanying drawings wherein:

FIG. 1 is a simplified equivalent circuit of a prior art Buck power converter;

FIG. 2 is a waveform diagram for the Buck converter circuit shown in figure 1 during a load transient;

FIG. 3 is a schematic diagram of a first embodiment of the present invention implemented in a Buck converter topology;

FIG. 4 is a waveform diagram showing the response of the first embodiment of the present invention when there is a fast transient increase in load current;

FIG. 5 is a waveform diagram showing the response of the first embodiment of the present invention when there is a fast transient decrease in load current;

FIG. 6 is a schematic diagram of a second embodiment of the present invention implemented in a Buck converter topology;

FIG. 7 is a schematic diagram of a third embodiment of the present invention implemented in a Buck converter topology;

FIG. 8 is a schematic diagram of a fourth embodiment of the present invention implemented in a Buck converter topology;

FIG. 9 is a schematic diagram of a fifth embodiment of the present invention implemented in a Buck converter topology;

FIG. 10 is a waveform diagram showing the response of the fifth embodiment of the present invention when there is a fast transient increase in load current; and

FIG. 11 is a waveform diagram showing the response of the fifth embodiment of the present invention when there is a fast transient decrease in load current;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] The discussion that follows describes embodiments of the present invention when incorporated into a buck power converter topology. It will be obvious to those skilled in the art that the present invention can also be applied to other power converter topologies such as a boost converter, a flyback converter, a forward converter, a push-pull converter, a resonant converter, a full bridge converter, a Cuk converter, a Sepic converter, a half bridge converter and other converter topologies. Referring now to the figures, figure 1 sets forth a prior art buck converter having two switches **M1** and **M2,** an output inductor **L1,** and an output capacitor **C1**. Figures 2 illustrates the operation of a typical buck converter when there is a step increase in the load current, assuming that the feedback circuit **4** and the Pulse Width Modulation controller 6, as shown in fig. 1, are fast enough to change the duty cycles of the converter switches **M1** and **M2** to enable the inductor current in inductor **L1** to rise to a new average. The rate of inductor current increase is limited by the inductance of the output inductor **L1**. An inductor **L1** with low inductance allows for a fast rate of inductor current change in the converter. But, the converter will suffer from having a high ripple inductor current. An inductor **L1** with high inductance will reduce the ripple current in the converter but the inductor current will transition more slowly. The references for the prior mentioned in Figs. 1 and 2 are US Patent No. 5,847,554 and US Patent No. 5,414,341.

[0017] The present invention provides a novel way of providing a fast inductor current rate change while at the same time providing a way of reducing the ripple current.

FIRST EMBODIMENT

[0018] Figure 3 sets forth a schematic diagram of a first embodiment of the present invention incorporated into a power converter. This embodiment comprises a power circuit **110** and a control circuit **120.** The power circuit **110** includes a pair of input terminals **101** and **102,** which are connectable to a DC voltage source to receive input power, and an output capacitor **C101** for providing regulated DC output power to a load **107** coupled to the output capacitor **C101**. The power circuit **110** further includes a pair of switches **M101** & **M102,** which in this embodiment are represented by MOSFETs but alternatively could be any of a number of suitable devices such as BITs, electromechanical, IGBTs, and semiconductor switches. The switches **M101 & M102** are controllable by the control circuit **120** to produce a series of alternating voltage pulses.

[0019] Coupled between the switches **M101** & **M102** and the output capacitor **C101** is a magnetic circuit **130.** The magnetic circuit **130** comprises a comparatively lower inductance fixed inductor **L101** and a comparatively higher inductance variable inductance device **140.** The variable inductance device **140** operates at a steady inductance level during normal operation of power circuit **110** to provide sufficient inductance to allow power circuit **110** to operate with low ripple voltage. When there is a fast transient current in power circuit **110,** variable inductance device **140** is operable to function at a reduced inductance level, preferably close to zero inductance, thereby improving the transient response of the power circuit **110.**

[0020] The variable inductance device **140** shown in this first embodiment of the invention consists of a transformer **T101** having three windings **W101**, **W102** and **W103.** Winding **W101** is coupled in series with fixed inductor **L101** and is coupled between the input terminals **101** and **102** and the output capacitor **C101.** Windings **W102** and **W103** are magnetically coupled to winding **W101** and are each coupled to a voltage source **Vi101.** In the embodiment shown, windings **W102** and **W103** are coupled to the same voltage source but, alternatively, could be coupled to different voltage sources. The windings **W102** and **W103** are also coupled to bi-directional switches **S103** and **S104**. Bi-directional switches **S103** and **S104** are operable to control the connection of voltage source **Vi101** to windings **W103** and **W102**, respectively. Bi-directional switching **S103** and **S104** could be any number of suitable devices such as MOSFETs, BJTs, IGBTs, and semiconductor switches.

[0021] The control circuit **120** comprises two loops, a Pulse Width Modulation (PWM) loop **105** and a variable inductance control loop **115.** The PWM loop **105** includes a feedback block **104** which is coupled to a PWM block **106.** The feedback block **104** is operable to monitor the converter load voltage, and the PWM block **106** is operable to provide driving pulses to the switches **M101** & **M102** in the power circuit **110.**

[0022] The variable inductance control loop **115** includes circuits that monitor the converter load voltage and produce driving signals for switches **S103** and **S104** in the power circuit **110.** The variable inductance control loop circuits, in the first embodiment, comprise a high pass filter **B101,** which is operable to monitor the converter load voltage, and two hysteresis comparators **B102** and **B103,** which are coupled to switches **S104** and **S103**, respectively.

[0023] During steady state operation, the feedback block **104** generates signals to control the PWM controller **106** which, in turn, generates gate pulses to drive MOSFETs **M101** and **M102** to maintain a steady voltage across the load **107**. The steady state operation is the same as that of a conventional converter, except that the output inductor consists of two series inductors **L101** and **W101** instead of one inductor. In the first embodiment, inductor **L101** is a separate physical inductor from winding **W101,** however, alternatively inductor **L101** could be leakage inductance and integrated with transformer **T101** so that there would be no need for a separate physical inductor. Also during steady state operation, the switches **S103** and **S104** are opened. Consequently, the inductance of **W101** is high to keep the ripple current low.

[0024] When there is a fast transient increase in load current, the converter of Fig. 3 responds to the transient condition as illustrated by the waveforms shown in Fig. 4. In the period between t10 and t11, the converter operates in steady state. At time t1 there is a step increase in load current as shown in Fig. 4C. This leads to an output voltage drop as shown in Fig. 4E.

[0025] When the output voltage drops below a threshold level **V1,** switch **S104** is switched on by the operation of filter **B101** and comparator **B102** thereby shorting voltage source **Vi101** to winding **W102.** As a result, the inductance of winding **W101** decreases and the equivalent inductance of inductors **L101** & **W101** decreases to the inductance of inductor **L101.** The current through inductor **L101,** consequently is capable of rising rapidly as shown in Fig. 4D due to the decreased inductance. In the time period between t12 and t13 current flows through winding **W102** as well. This current consists of the reflected current from winding **W101** and magnetizing current resulting from voltage source **Vi101** being applied to winding **W102.** The magnitude of the current flowing through winding **W102** is dependent on the turns ratio of windings **W101** and **W102.** As a result of the increase in the current through inductor **L101** and the magnetizing current flowing through transformer **T101,** the output voltage increases. When the output voltage reaches a second voltage level V2 at time t13, switch **S104** is turned off.

[0026] At time t13, switch **S104** is off and the current through winding **W102** falls to zero during the time period t13 to t14. When switch **S104** is off, the magnetizing current of transformer **T101** will be coupled to winding **W101.**

At time t13, the current flowing through inductor **L101** and the magnetizing current flowing through winding **W101** may not necessarily be the same. The difference in current will charge up the stray capacitance of switch **S104** and create a voltage spike in winding **W101** during the time period between t13 and t14 as shown in Fig. 4H. An energy absorption circuit such as a snubber circuit could be employed to guard against overvoltage in winding **W101.** Such an energy absorption circuit could alternatively be coupled to inductor **L101**, transformer **T101**, switch **S103** or switch **S104.**

[0027] After, time t14 the equivalent series output inductance of power circuit becomes higher than it was during the transient period because, at time t14, the equivalent series output inductance includes the inductance of inductor **L101** and winding **W101.** The output inductor current cannot change as rapidly as when inductor **W101** is effectively at zero inductance. If the inductor current is sufficient to meet the load demands, the output voltage will rise and the PWM loop **105** will resume its normal pulse width modulation. It is possible, however, that the inductor current at time t14 may not be sufficient to meet the load current demands and, as a result, the output voltage may fall after switch **S104** has switched to an off-state at t14. In this case, the output voltage may decrease below the threshold level V1 and switch **S104** may be switched to an on state again. If this happens, the cycle is repeated until the inductor current through **L101** is sufficient to meet the load current demands. Eventually, the output voltage will rise to a level so that normal pulse width modulation may resume.

[0028] When there is a fast transient decrease in load current, the converter responds to the transient condition as shown in Fig. 5. During the time period between t20 and t21, the converter operates with a steady load current. At time t21, there is a step decrease in the load current as shown in Fig. 5C. As a result, the output voltage rises as shown in Fig. 5E. Even if the PWM loop **105** is fast enough to turn off MOSFET **M101** and turn on MOSFET **M102,** the current reduction in inductor **L101** will still be too slow because of the high combined inductance of inductor **L101** and winding **W101.** When the output voltage reaches a threshold level **V3** at time t22, filter **B101** and comparator **B103** triggers switch **S103** to switch to an on-state. As a result, winding **W103** is coupled to the voltage source **Vi101**, the inductance of winding **W101** effectively decreases to zero, and winding **W103** allows for a rapid decrease in output inductor current through **W101.** A magnetizing current is also generated in winding **W103.**

[0029] The reduction in output inductor current causes the output voltage to decrease until it reaches a threshold voltage level **V4** at time t23. At this time, switch **S103** is switched to an off state and the magnetizing current is transferred to winding **W101.** The magnetizing current may not match the current flow in inductor **L101** thereby causing a voltage spike across winding **W101** in the time period t23 to t24 as shown in Fig. 5H. An energy absorption circuit such as a snubber circuit can be employed to avoid overvoltage in winding **W101.** An appropriate energy absorption circuit may be coupled, alternatively, to inductor **L101**, transformer **T101**, switch **S103** or switch **S104.**

[0030] In the time period after time t24, the output voltage gradually reduces to an appropriate level so that the PWM loop **105** resumes normal operation. It is possible, however, that the current through inductor **L101** may not have fallen sufficiently to prevent the output voltage from reaching voltage threshold level **V3** after time t24. In this case, the process will repeat until the inductor current is sufficiently reduced.

[0031] During steady state operation, the equivalent series inductance of the series inductors is the summation of the inductance. The inductor **W1** is designed to have a high enough inductance to minimize the ripple current thereby minimizing RMS current flowing through the switching elements and other components. The inductor **L101** is designed to have a low enough inductance to provide a fast rate of current charge when the inductor **W101** is shorted out during transient conditions. Transient conditions only exist for a short time and the converter spends most of its operating time in the steady state. Hence the converter will have a high ripple current only for a short duration and efficiency will not be seriously impaired. This invention is versatile and can be applied to most switching converters which use an output inductor.

[0032] As shown in the description of the first embodiment, the present invention provides a means to keep the output voltage of a converter within limits and is able to provide a fast transient response when faced with sudden load current changes.

SECOND EMBODIMENT

[0033] Figure 6 sets forth a schematic diagram of a second embodiment of the present invention incorporated into a power converter. This embodiment differs from the first embodiment in that the auxiliary voltage source of the first embodiment is eliminated by the use of the input voltage source as the auxiliary voltage source. This second embodiment comprises a power circuit **210** and a control circuit **220.**

[0034] The power circuit **210** includes a pair of input terminals **201** and **202,** which are connectable to a DC voltage source to receive input power, and an output capacitor **C201** for providing regulated DC output power to a load **207** coupled to the output capacitor **C201.** The power circuit **210** further includes a pair of switches **M201 & M202**, which in this embodiment are represented by MOSFETs but, alternatively, could be any of a number of suitable devices such as **BJTs**, electromechanical switches, IGBTs, and semiconductor switches. The switches **M101 & M102** are controllable by the control circuit **220** to produce a series of alternating voltage pulses.

[0035] Coupled between the switches **M201** & **M202** and the output capacitor **C201** is a magnetic circuit **230.** The magnetic circuit **230** comprises a comparatively lower inductance fixed inductor **L201** and a comparatively higher inductance variable inductance device **240.** The variable inductance device **240** operates at a steady inductance level during normal operation of power circuit **210** to provide sufficient inductance to allow power circuit **210** to operate with low ripple voltage. When there is a fast transient current in power circuit **210,** variable inductance device **240** is operable to function at a reduced inductance level, preferably close to zero inductance, thereby improving the transient response of the power circuit **210.**

[0036] The variable inductance device **240** shown in this second embodiment of the invention consists of a transformer **T201** having three windings **W201**, **W202** and **W203.** Winding **W201** is coupled in series with fixed inductor **L201** and is coupled between the input terminals **201** and **202** and the output capacitor **C201.** Windings **W202** and **W203** are magnetically coupled to winding **W201** and are each coupled to the input voltage terminal **201.** The windings **W202** and **W203** are also coupled to bi-directional switches **S203** and **S204**. Bi-directional switches **S203** and **S204** are operable to control the connection of the input voltage source to windings **W203** and **W202**, respectively.

[0037] The control circuit **220** comprises two loops, a Pulse Width Modulation (PWM) loop **205** and a variable inductance control loop **215.** The PWM loop **215** includes a feedback block **204** which is coupled to a PWM block **206.** The feedback block **204** is operable to monitor the converter load voltage, and the PWM block **206** is operable to provide driving pulses to the switches **M201** & **M202** in the power circuit **210.**

[0038] The variable inductance control loop **215** includes circuits that monitor the converter load voltage and produce driving signals for switches **S203** and **S204** in the power circuit. The variable inductance control loop circuits, in the second embodiment, comprise a high pass filter **B201**, which is operable to monitor the converter load voltage, and two hysteresis comparators **B202** and **B203,** which are coupled to switches **S204** and **S203,** respectively.

[0039] The operation of the power circuit **210** and the control circuit **220** of the second embodiment is the same as the power circuit **110** and the control circuit **120** of the first embodiment. Appropriate turns ratio of windings in transformer **T201** are used.

THIRD EMBODIMENT

[0040] Figure 7 sets forth a schematic diagram of a third embodiment of the present invention incorporated into a power converter. This embodiment differs from the first embodiment, primarily, in that the auxiliary voltage source of the first embodiment is eliminated by the use of the output voltage source as the auxiliary voltage source. In addition, two clamping diodes are employed to protect the switches from overvoltage. This third embodiment comprises a power circuit **310** and a control circuit **320.**

[0041] The power circuit **310** includes a pair of input terminals **301** and **302,** which are connectable to a DC voltage source to receive input power, and an output capacitor **C301** for providing regulated DC output power to a load **307** coupled to the output capacitor **C301 .** The power circuit **310** further includes a pair of switches **M301** & **M302,** which in this embodiment are represented by MOSFETs. The switches **M301** & **M302** are controllable by the control circuit **320** to produce a series of alternating voltage pulses.

[0042] Coupled between the switches **M301** & **M302** and the output capacitor **C301** is a magnetic circuit **330.** The magnetic circuit **330** comprises a comparatively lower inductance fixed inductor **L301** and a comparatively higher inductance variable inductance device **340.** The variable inductance device **340** operates at a steady inductance level during normal operation of power circuit **310** to provide sufficient inductance to allow power circuit **310** to operate with low ripple voltage. When there is a fast transient current in power circuit **310,** variable inductance device **340** is operable to function at a reduced inductance level, preferably close to zero inductance, thereby improving the transient response of the power circuit **310.**

[0043] The variable inductance device **340** shown in this third embodiment of the invention consists of a transformer **T301** having three windings **W301**, **W302** and **W303.** Winding **W301** is coupled in series with fixed inductor **L301** and is coupled between the input terminals **301** and **302** and the output capacitor **C301.** Windings **W302** and **W303** are magnetically coupled to winding **W301** and are each coupled to the output voltage terminal **303.** The windings **W302** and **W303** are also coupled to bi-directional switches **S303** and **S304**. Bi-directional switches **S303** and **S304** are operable to control the connection of the output voltage source to windings **W303** and **W302**, respectively. Two diodes **D303** and **D304** are coupled to switches **S303** and **S304** respectively which clamp the switch voltages to the input voltage level.

[0044] The control circuit **320** comprises two loops, a Pulse Width Modulation (PWM) loop **305** and a variable inductance control loop **315.** The PWM loop **305** includes a feedback block **304** which is coupled to a PWM block **306.** The feedback block **304** is operable to monitor the converter load voltage, and the PWM block **306** is operable to provide driving pulses to the switches **M301** & **M302** in the power circuit **310.**

[0045] The variable inductance control loop **315** includes circuits that monitor the converter load voltage and produce driving signals for switches **S303** and **S304** in the power circuit. The variable inductance control loop circuits, in the third embodiment, comprise a high pass filter **B301,** which is operable to monitor the converter load voltage, and two hysteresis comparators **B302** and

B303, which are coupled to switches **S304** and **S303**, respectively.

[0046] The operation of the power circuit **310** and the control circuit **320** of the third embodiment is the same as the power circuit **110** and the control circuit **120** of the first embodiment. Appropriate turns ratio of windings in transformer **T301** are used.

FOURTH EMBODIMENT

[0047] Figure 8 sets forth a schematic diagram of a fourth embodiment of the present invention incorporated into a power converter. This embodiment differs from the second embodiment, primarily, in that AND circuits **IC403** and **IC404** are added to ensure that the switching of switches **S403** and **S404** is coordinated with the switching of switches **M401** and **M402.** Also clamping clamping diodes **D403** and **D404** are added to clamp voltage spikes that may be generated in the winding **W401** as a result of a fast transient. This fourth embodiment also comprises a power circuit **410** and a control circuit **420.**

[0048] The power circuit **410** includes a pair of input terminals **401** and **402**, which are connectable to a DC voltage source to receive input power, and an output capacitor **C401** for providing regulated DC output power to a load **407** coupled to the output capacitor **C401.** The power circuit **410** further includes a pair of switches **M401** & **M402,** which in this embodiment are represented by MOSFETs **M401** and **M402.** The switches **M401** & **M402** are controllable by the control circuit **420** to produce a series of alternating voltage pulses.

[0049] Coupled between the switches **M401** & **M402** and the output capacitor **C401** is a magnetic circuit **430.** The magnetic circuit **430** comprises a comparatively lower inductance fixed inductor **L401** and a comparatively higher inductance variable inductance device **440.** The variable inductance device **440** operates at a steady inductance level during normal operation of power circuit **410** to provide sufficient inductance to allow power circuit **410** to operate with low ripple voltage. When there is a fast transient current in power circuit **410,** variable inductance device **440** is operable to function at a reduced inductance level, preferably close to zero inductance, thereby improving the transient response of the power circuit **410.**

[0050] The variable inductance device **440** shown in this fourth embodiment of the invention consists of a transformer **T401** having three windings **W401**, **W402** and **W403.** Winding **W401** is coupled in series with fixed inductor **L401** and is coupled between the input terminals **401** and **402** and the output capacitor **C401.** Two clamping diodes **D403** and **D404** are coupled to the node joining inductor **L401** and winding **W401.** Windings **W402** and **W403** are magnetically coupled to winding **W401** and are each coupled to the input voltage terminal **401.** The windings **W402** and **W403** are also coupled to bi-directional switches **S403** and **S404.** Bi-directional switches **S403** and **S404** are operable to control the connection of the output voltage source to windings **W403** and **W402**, respectively.

[0051] The control circuit **420** comprises two loops, a Pulse Width Modulation (PWM) loop 405 and a variable inductance control loop **415.** The PWM loop **405** includes a feedback block **404** which is coupled to a PWM block **406**. The feedback block **404** is operable to monitor the converter load voltage, and the PWM block **406** is operable to provide driving pulses to the switches **M401** & **M402** in the power circuit **410**.

[0052] The variable inductance control loop **415** includes circuits that monitor the converter load voltage and produce driving signals for switches **S403** and **S404** in the power circuit. The variable inductance control loop circuits, in the fourth embodiment, comprise a high pass filter **B401**, which is operable to monitor the converter load voltage, and two hysteresis comparators **B402** and **B403,** which are coupled to AND gates **IC403** and **IC404** which, in turn, synchronize the switching of switches **S403** and **S404** with those of the main switches **M402** and **M401**, respectively.

[0053] The operation of the power circuit **410** and the control circuit **420** of the fourth embodiment is the same as the power circuit **210** and the control circuit **220** of the second embodiment except for the functionality changed due to the addition of the clamping diodes and the additional AND gates.

[0054] Diodes **D403** and **D404** clamp the voltage at the node joining inductor **L401** and winding **W401** during the transient when either switch **S403** or **S404** transition off. When these switches transition off, often there is a mismatch of current through winding **W401** before and after the turn off transient. This transient may generate voltage spikes which will be clamped by diodes **D403** and **D404** in order to recover the energy involved.

[0055] The addition of AND gate **IC403** ensures that switch **S403** is switched to an on state only when main switch **M402** is switched to an on state even in the presence of a transient load current change. When there is a transient decrease in load current, winding **W403** reduces the effective inductance of winding **W401** only if switch **M402** is switched to an on state to induce a decrease in current flow through inductor **L401**. This ensures the inductor current can decrease rapidly to meet the load demand.

[0056] The addition of AND gates **IC404** ensures that switch **S404** is switched to an on state only when main switch **M401** is switched to an on state even in the presence of a transient load current change. When there is a transient increase in load current, winding **W402** reduces the effective inductance of winding **W401** only if switch **M401** is switched to an on state to induce an increase of current flow through inductor **L401.** This ensures the inductor current can increase rapidly to meet the load demand.

FIFTH EMBODIMENT

[0057] Figure 9 sets forth a fifth embodiment of the present invention incorporated into a power converter. In this embodiment, a different type of variable inductance device is employed. In this embodiment, the variable inductance device comprises a comparatively smaller inductor **L501** coupled in series with a switch **S503**, the combination being coupled in parallel with a comparatively larger inductor **L502.** The switch **S503** during normal operation of the converter is opened to isolate the small inductor **L501** from the converter. When there is a transient change in the load voltage, the switch **S503** is closed thereby coupling the small inductor **L501** in parallel with the large inductor **L502** and enabling fast current change. This fifth embodiment also comprises a power circuit **510** and a control circuit **520.**

[0058] The power circuit **510** includes a pair of input terminals **501** and **502**, which are connectable to a DC voltage source to receive input power, and an output capacitor **C501** for providing regulated DC output power to a load **507** coupled to the output capacitor **C501.** The power circuit **510** further includes a pair of switches **M501** & **M502,** which in this embodiment are represented by MOSFETs **M501** and **M502.** The switches **M501** & **M502** are controllable by the control circuit **520** to produce a series of alternating voltage pulses.

[0059] Coupled between the switches **M501** & **M502** and the output capacitor **C501** is the variable inductance device **540** of this embodiment. The variable inductance device **540** operates at a high steady inductance level during normal operation of power circuit **510** to provide sufficient inductance to allow power circuit **510** to operate with low ripple voltage. When there is a fast transient current in power circuit **510**, variable inductance device **540** is operable to function at a reduced inductance level thereby improving the transient response of the power circuit **510.**

[0060] The variable inductance device **540** shown in this fifth embodiment of the invention consists of an inductor **L501** with a series switch **S503** coupled in parallel with inductor **L502**. Two voltage clamping diodes **D503** and **D504** are coupled to the node between switch **S503** and inductor **L501** to protect switch **S503.**

[0061] The control circuit **520** comprises two loops, a Pulse Width Modulation (PWM) loop **505** and a variable inductance control loop **515**. The PWM loop **505** includes a feedback block **504** which is coupled to a PWM block **506**. The feedback block **504** is operable to monitor the converter load voltage, and the PWM block **506** is operable to provide driving pulses to the switches **M501** & **M502** in the power circuit **510.**

[0062] The variable inductance control loop **515** includes circuits that monitor the converter load voltage and produce driving signals for switch **S503**. The variable inductance control loop circuits, in the fifth embodiment, comprise a high pass filter **B501**, which is operable to monitor the converter load voltage, and two hysteresis comparators **B502** and **B503.** The output of the two hysteresis comparators **B502** and **B503** input to a logic circuit **525** comprising AND gates **IC503** and **IC504** and OR gate **IC505.** Logic circuit **525** is operable to synchronize the switching of switch **S503** with the switching of the main switches **M402** and **M401.**

[0063] During steady state operation, the feedback block **504** generates signals to control the PWM controller **506** which, in turn, generates gate pulses to drive MOSFETs **M501** and **M502** to maintain a steady voltage across the load **507.** The steady state operation is the same as that for a conventional converter having an output inductor **L502** and an output capacitor **C501.** Also during steady state operation, the switch **S503** is in an open state so that inductor **L501** does not affect the power conversion operation of the converter. Inductor **L502** has a high enough inductance to suppress excessive ripple current. This provides for high efficiency during steady load operation. Inductor **L501** has a considerably lower inductance than that of inductor **L502.**

[0064] When there is a fast transient increase in load current, the present converter responds to the transient condition as illustrated by the waveforms shown in Fig. 10. In the period between t30 and t31, the converter operates in steady state. At time t31 there is a step increase in load current as shown in Fig. 10C. This leads to an output voltage drop as shown in Fig. 10E. When the output voltage drops below a threshold level **V11**, switch S503 is switched on by the operation of filter **B501**, comparator **B502,** AND gate **IC504,** and OR gate **IC505.** As a result, inductor **L501**, which has a lower inductance, is connected in parallel with inductor **L502.** This reduces the overall converter inductance and, consequently, inductor current can rise rapidly as shown in Fig 10D.

[0065] In the time period between t32 and t33, current flows through inductor **L501** as well. This current causes the output voltage to increase. When the output voltage reaches a second voltage level **V12** at time t33, as shown in Fig. 10, switch **S503** is switched to an off state by the operation of filter **B501**, comparator **B502**, AND gate **IC504**, and OR gate **IC505.** Current flowing through inductor **L501** is diverted through diode **D504** and decreases until time t34. At time t34, diode **D504** turns off and the current through inductor **L501** diminishes to zero.

[0066] During the time period t32 to t34, the current in inductor **L502** rises. If the current rose enough to support the load demands from time t34 and beyond, the converter will resume normal pulse width modulation with switches **M501** and **M502.** If the current has not risen sufficiently to meet load demands, the output voltage will drop back to voltage level V11 and the sequence will be re-initiated to boost the output voltage. Eventually, the output voltage will rise to a level so that normal pulse width modulation may resume.

[0067] When there is a fast transient decrease in load current, the converter of Fig. 9 responds to the transient condition as shown in Fig.11. During the time period between t40 and t41, the converter operates with a steady load current. At time t41, there is a step decrease in the load current as shown in Fig. 11C. As a result, the output voltage rises as shown in Fig. 11E. Even if the PWM loop **520** is fast enough to turn off MOSFET **M501** and turn on MOSFET **M502**, the current reduction in inductor **L502** is still too slow because of the high inductance of inductor **L502.** When the output voltage reaches a threshold level **V13** at time t42, switch **S503** is switched to an on state by the operation of filter **B501,** comparator **B503,** AND gate **IC503,** and OR gate **IC505.** As a result, inductor **L501** which has much smaller inductance is connected in parallel with inductor **L502.** This reduces the overall converter inductance and current can change rapidly as shown in Fig. 11D.

[0068] During the time between t42 and t43, current increases in the negative sense through inductor **L501.** This current causes the output voltage to decrease until the output voltage reaches voltage level **V14** as shown in Fig. 11E**.** When voltage level **V14** is reached, switch **S503** is switched to an off state by the operation of filter **B501,** comparator **B503**, AND gate **IC503**, and OR gate **IC505.** Current flowing through inductor **L501** is diverted through diode D503 and reduced until time t44. At time t44 diode **D503** is turned off and current flowing through inductor **L501** diminishes to zero.

[0069] During time period t42 to t44, current flowing through inductor also decreases. If the inductor current has decreased enough to sufficiently reduce the output voltage at time t34 and beyond, the converter will resume normal pulse with modulation. If the inductor current has not decreased sufficiently, the output voltage will increase again to voltage level **V13** and the whole process will be re-initiated to step down the output voltage.

[0070] The present invention has been described with reference to a buck converter topology. It would be obvious, however, to those skilled in the art to apply the invention to other converter topologies such as a boost converter, a flyback converter, a forward converter, a push-pull converter, a resonant converter, a full bridge converter, a Cuk converter, a Sepic converter, a half bridge converter and other converter topologies, without departing from the scope of the present invention which is defined by the following claims. A number of embodiments that have particular utility for fast transient applications in switching power converters have been described. The embodiments described herein are just a few of the embodiments that may be generated by those skilled in the art using the invention described herein.

Claims

1. A power converter comprising:

   an input (101, 102) for receiving input power;
   an output for providing regulated output power;
   a variable inductance device (130, 540) coupled between the input and the output, said variable inductance device (130, 540) having a higher inductance state and a lower inductance state, said variable inductance device being controllable to switch between said higher inductance state and said lower inductance state; and
   a control circuit (120, 520) that is operable to sense voltage at the output;

   characterized in that
   said control circuit is operable to signal said variable inductance device:

   to switch to said lower inductance state when the voltage at the output falls bellow a first voltage level (V_{11}),
   to switch to said higher inductance state when the voltage at the output rises above a second voltage level (V_{12}) that is higher than said first voltage level V($_{11}$),
   to switch to said lower inductance state when the voltage at the output rises above a third voltage level (V_{13}) and
   to switch to said higher inductance state when the voltage at the output falls bellow a fourth level (V_{14}) that is lower than third voltage level (V_{13}), whereby said fourth voltage level (V_{14}) is higher than said second voltage level (V_{12}).

2. The power converter of claim 1 wherein said variable inductance device (130) comprises a fixed inductance component (L101) and a variable inductance component (140), said variable inductance component (140) coupled in series with said fixed inductance component (L101), said variable inductance component (140) comprising a transformer (T101) having a plurality of windings (W101, W102, W103).

3. The power converter of claim 2 wherein said transformer (T101) has three windings (W101, W102, W103).

4. The power converter of claim 2 or 3 wherein a first winding (W101) of said transformer (T101) is in series with said-fixed inductance component (L101).

5. The power converter of claim 4 further comprising an auxiliary power source (Vi101) that is coupled in series with a second winding (W102) of said transformer (T101) and a first switch (S104).

6. The power converter of claim 5 wherein said auxiliary power source (Vi101) is coupled in series with a third winding (W103) of said transformer (T101) and a second switch (S103).

7. The power converter of claim 5 or 6 wherein said auxiliary power source (Vi101) is coupled to said input power source.

8. The power converter of claim 5 or 6 wherein said auxiliary power source (Vi101) is coupled to said output.

9. The power converter according to claim 1, wherein said variable inductance device (540) comprises:

a lower inductance element (L501);
a switch (S503) coupled in series with said lower inductance element (L501) thereby forming a switch and lower inductance element series combination (S503, L501); and
a higher inductance element (L502) coupled in parallel with said switch and lower inductance element series combination (S503, L501);

wherein said switch (S503) is operable to switch said variable inductance device (540) between said lower inductance state and said higher inductance state.

10. The power converter of any of claims 1 to 9 wherein said control circuit (120, 520) comprises a first comparator (B102, B502), said first comparator being operable to sense voltage at said output and to signal said variable inductance device (130, 540) to switch from said high inductance state to said low inductance state in response to the sensed output voltage.

11. The power converter of claim 10 wherein said control circuit (120, 520) further comprises a second comparator (B103, B503), said second comparator being operable to sense voltage at said output and to signal said variable inductance device (130, 540) to switch from said low inductance state to said high inductance state in response to the sensed output voltage.

12. The power converter of claim 11 further comprising a pulse width modulation controller (506) coupled to said switch (S503), said pulse width modulation controller (506) being operable to signal said switch (S503) to switch said variable inductance device (540) between said lower inductance state and said higher inductance state.

13. The power converter of any of claims 1 to 12 further comprising:

switch means (M101, M102) coupled to said variable inductance device (130), said switch means having a first state and a second state, said switch means being operable to allow input power to reach said variable inductance device when being in
said first state, said switch means being operable to resist the flow of input power to said variable inductance device when being in said second state; and
a pulse width modulation controller (106) coupled to said switch means (M101, M102), said pulse width modulation controller (106) being operable to signal said switch means to switch in between said first state and said second state.

14. The power converter of claim 13 further comprising means (IC403, IC404) operable to signal said variable inductance device (130, 430) to switch from said high inductance state to said low inductance state when said switch means (M401, M402) is in said first state, said means (IC403, IC404) also being operable to signal said variable inductance device to switch from said low inductance state to said high inductance state when said switch means (M401, M402) is in said second state.

15. The power converter according to claim 1, wherein said variable inductance device (130) comprises:

a first inductor (L101);
a first transformer (T101) having a plurality of windings (W101, W102, W103) magnetically coupled with one another, said transformer (T101) including a first winding (W101) coupled to said first inductor (L101), a second winding (W102), and a third winding (W103);
a voltage source (Vi101);
a first switch (S104) coupled to said second winding (W102) and operable to couple voltage from said voltage source (Vi101) to said second winding (W102);
a second switch (S103) coupled to said third winding (W103) and operable to couple voltage from said voltage source (Vi101) to said third winding (W103);

said control circuit (120) comprises:

a first control circuit (B102) that is operable to cause said first switch (S104) to couple said voltage from said voltage source (Vi101) to said second winding (W102);
a second control circuit (B103) that is operable to cause said second switch (S103) to couple said voltage from said voltage source (Vi101) to said third winding (W103); and

said power converter further comprises:

a first node that provides switching voltage pulses;
a unit, comprising said first inductor (L101) and first transformer (T101), coupled to said first node that provides switching voltage pulses;
an output capacitor (C101) coupled to said unit and to a return node of said converter;
output terminals coupled to said output capacitor (C101) for connection to a load (107); and

an overvoltage protection circuit that is operable to guard said first and said second switches (S104, S103) against exposure to overvoltages.

16. The power converter according to claim 15 further comprising means (B101, B102, B103) for monitoring converter load voltage at said output terminals; and wherein
said first control circuit (B102) is operable to cause said first switch (S104) to couple said voltage from said voltage source (Vi101) to said second winding (W102) when said load voltage falls below said first voltage level, said first control means (B102) being operable to cause said first switch (S104) to decouple said voltage source (Vi101) from said second winding (W102) when said load voltage rises above said second voltage level; and
said second control circuit (B103) is operable to cause said second switch (S103) to couple said voltage source (Vi101) to said third winding (W103) when said load voltage rises above said third voltage level, said second control means (B103) being further operable to cause said second switch (S103) to decouple said voltage source (Vi101) from said third winding (W103) when said load voltage falls below said fourth voltage.

17. The power converter according to claim 1, wherein said variable inductance device (230) comprises:

a first inductor (L201);
a first transformer (T201) having a plurality of windings magnetically coupled with one another, said windings including a first winding (W201) coupled to said first inductor (L201), a second winding (W202), and a third winding (W203);
a first switch (S204) coupled to said second winding (W202);
a second switch (S203) coupled to said third winding (W203);

said power converter further comprises:

a pair of input terminals (201, 202) for connection to a DC voltage source, the first of said terminals being a positive terminal and the second of said terminals being a negative terminal;
a first node that provides switching voltage pulses;
a unit, comprising the said first inductor (L201) and first transformer (T201), coupled to said first node that provides switching voltage pulses;
an output capacitor (C201) coupled to said unit and to a return node of said converter;
a pair of output terminals, the first of said output terminals being a positive terminal and the second of said output terminals being a negative terminal, coupled to said output capacitor (C201) for providing a connection point for a load (207); and
an overvoltage protection circuit that is operable to guard said first and said second switches (S204, S203) against exposure to overvoltages; and

said control circuit (220) comprises:

a first control circuit (B202) that is operable to cause said first switch (S204) to couple said second winding (W202) to said output capacitor (C201); and
a second control circuit (B203) that is operable to cause said second switch (S203) to couple said third winding (W203) to said output capacitor (C201).

18. The power converter according to claim 17 wherein said overvoltage protection circuit comprises:

a first diode (D304) with its cathode coupled to said positive input terminal (301) and its anode coupled to a node joining said second winding (W302) and said first switch (S304); and
a second diode (D303) with its cathode coupled to said positive input terminal (301) and its anode coupled to a node joining said third winding (W303) and said second switch (S303).

19. The power converter according to claim 17 wherein said overvoltage protection circuit comprises:

a first diode (D404) with its anode coupled to a node joining said first inductor (L401) and said first transformer winding (W401) and its cathode coupled to said positive input terminal (402); and
a second diode (D403) with its anode coupled to said negative input terminal (401) and its cathode coupled to a node joining said second winding (W402) and said third winding (W403).

20. The power converter according to any of claims 17 to 19 further comprising means (B201, B202, B203) for monitoring the converter load voltage at said output terminals; and wherein
said first control circuit (B202) is operative to cause said first switch (S204) to couple said second winding (W202) to said output capacitor (C201) when said load voltage falls below said first voltage level, said first control circuit (B202) also being operative to cause said first switch (S204) to decouple said second winding (W202) from said output capacitor (C201) when said load voltage rises above said second voltage level; and
said second control circuit (B203) is operative to cause said, second switch (S203) to couple said third winding (W203) to said output capacitor (C201)

when said load voltage rises above said third voltage level, said second control circuit (B203) being further operative to cause said second switch (S203) to decouple said third winding (W203) from said output capacitor (C201) when said load voltage falls below said fourth voltage.

21. The power converter according to claim 20 further comprising:

first means (IC404) for switching said first switch (S404) to an on-state only if a high pulse voltage is coupled to said first inductor (L401); and
second means (IC403) for switching said second switch (S403) to an on-state only if a low pulse voltage is coupled to said first inductor (L401).

22. The power converter according to claim 1, wherein said variable inductance device (540) comprises:

a first inductor (L502) coupled to a first node that provides switching voltage pulses having a high voltage level and a low voltage level;
a second inductor (L501) coupled in series to a first series switch (S503) thereby forming an inductor series-switch combination, said combination being coupled in parallel with said first inductor (L502);

said control circuit (520) is operable to cause said first series switch (S503) to couple said second inductor (L501) in parallel with said first inductor (L502); and
said power converter further comprises:

a pair of input terminals (501, 502) for connection to a DC voltage source, the first of said terminals being a positive terminal and the second of said terminals being a negative terminal;
a first diode with its cathode coupled to said positive input terminal and its anode coupled to a node joining said second inductor (L501) and said first series switch (S503);
a second diode with its anode coupled to said negative input terminal and its cathode coupled to a node joining said second inductor (L501) and said first series switch (S503);
an output capacitor (C501) coupled to said first inductor (L502) and a return node of the converter;
a pair of output terminals coupled to said output capacitor (C501) for providing a connection point for a load (507); and
an overvoltage protection circuit that is operable to guard said first switch against exposure to an overvoltage.

23. The power converter according to claim 22 further comprising means (B501, B502, B503) for monitoring the converter load voltage at said output terminals; and wherein
said control circuit (525) is operative to cause said first series switch (S503) to couple said second inductor (L501) in parallel with said first inductor (L502) when said load voltage falls below said first voltage level, said control circuit (525) also being operative to cause said first series switch (S503) to decouple said second inductor (L501) from said first inductor (L502) when said load voltage rises above said second voltage level,
said control circuit (525) being further operative to cause said first series switch (S503) to couple said second inductor (L501) in parallel with said first inductor (L502) when said load voltage rises above said third voltage level, said control circuit (525) also being operative to cause said first series switch (S503) to decouple said second inductor (L501) from said first inductor (L502) when said load voltage falls below said fourth voltage level.

24. The power converter according to claim 23 further comprising:

first means (IC504) for switching said first series switch (S503) to an on-state only if a high pulse voltage is coupled to said first inductor (L502); and
second means (IC503) for switching said first series switch (S503) to an off-state only if a low pulse voltage is coupled to said first inductor (L502).

25. A device comprising a power converter according to any of claims 1 to 24 and an electrical load coupled to said output to receive regulated output power.

Patentansprüche

1. Leistungswandler mit:

einem Eingang (101,102) zum Empfangen von Eingangsleistung;
einem Ausgang zum Bereitstellen einer geregelten Ausgangsleistung;
einer variablen Induktivitätseinrichtung (130, 540), die zwischen dem Eingang und dem Ausgang angeschlossen ist, wobei die variable Induktivitätseinrichtung (130, 540) einen Zustand mit höherer Induktivität und einen Zustand mit niedrigerer Induktivität aufweist, wobei die variable Induktivitätseinrichtung steuerbar ist, so dass zwischen dem Zustand mit höherer Induktivität und dem Zustand mit niedrigerer Induktivität umgeschaltet werden kann; und

einer Steuerschaltung (120, 520) die ausgebildet ist, eine Spannung an dem Ausgang zu erfassen;

dadurch gekennzeichnet, dass
die Steuerschaltung ausgebildet ist, der variablen Induktivitätseinrichtung anzuzeigen:

in den Zustand mit niedrigerer Induktivität zu schalten, wenn die Spannung an dem Ausgang unter einen ersten Spannungspegel (V_{11}) fällt,
in den Zustand mit höherer Induktivität zu schalten, wenn die Spannung an dem Ausgang über einen zweiten Spannungspegel (V_{12}) ansteigt, der höher als der erste Spannungspegel (V_{11}) ist,
in den Zustand mit niedrigerer Induktivität zu schalten, wenn die Spannung an dem Ausgang über einen dritten Spannungspegel (V_{13}) ansteigt, und
in den Zustand mit höherer Induktivität zu schalten, wenn die Spannung an dem Ausgang unter einen vierten Spannungspegel (V_{14}) fällt, der tiefer liegt als der dritte Spannungspegel (V_{13}), wobei der vierte Spannungspegel (V_{14}) höher ist als der zweite Spannungspegel (V_{12}).

2. Leistungswandler nach Anspruch 1, wobei die variable Induktivitätseinrichtung (130) eine feste Induktivitätskomponente (L101) und eine variable Induktivitätskomponente (140) aufweist, wobei die variable Induktivitätskomponente (140) mit der festen Induktivitätskomponente (L101) in Reihe geschaltet ist, und wobei die variable Induktivitätskomponente (140) einen Transformator (T101) mit mehreren Wicklungen (W101, W102, W103) aufweist.

3. Leistungswandler nach Anspruch 2, wobei der Transformator (T101) drei Wicklungen (W101, W102, W103) aufweist.

4. Leistungswandler nach Anspruch 2 oder 3, wobei eine erste Wicklung (W101) des Transformators (T101) mit der festen Induktivitätskomponente (L101) in Reihe geschaltet ist.

5. Leistungswandler nach Anspruch 4, der ferner eine Hiffsleistungsquelle (Vi101) aufweist, die mit einer zweiten Wicklung (W102) des Transformators (T101) und einem ersten Schalter (S104) in Reihe geschaltet ist.

6. Leistungswandler nach Anspruch 5, wobei die Hilfsleistungsquelle (Vi101) mit einer dritten Wicklung (W103) des Transformators (T101) und einem zweiten Schalter (S103) in Reihe geschaltet ist.

7. Leistungswandler nach Anspruch 5 oder 6, wobei die Hilfsleistungsquelle (Vi101) mit der Eingangsleistungsquelle verbunden ist.

8. Leistungswandler nach Anspruch 5 oder 6, wobei die Hilfsleistungsquelle (Vi101) mit dem Ausgang gekoppelt ist.

9. Leistungswandler nach Anspruch 1, wobei die variable Induktivitätseinrichtung (540) umfasst:

ein Element mit niedrigerer Induktivität (L501);
einen Schalter (S503), der mit dem Element mit niedrigerer Induktivität (L501) in Reihe geschaltet ist, wodurch eine Reihenschaltung (S503, L501) eines Schalters und dem Element mit niedrigerer Induktivität gebildet ist; und
ein Element mit höherer Induktivität (L502), das parallel zu der Reihenschaltung aus dem Schalter und dem Element mit niedrigerer Induktivität (S503, L501) geschaltet ist;

wobei der Schalter (S503) ausgebildet ist, die variable Induktivitätseinrichtung (540) von dem Zustand mit niedrigerer Induktivität in den Zustand mit höherer Induktivität und umgekehrt zu schalten.

10. Leistungswandler nach einem der Ansprüche 1 bis 9, wobei die Steuerschaltung (120, 520) einen ersten Komparator (8102, B502) aufweist, wobei der erste Komparator ausgebildet ist, die Spannung an dem Ausgang zu erfassen und der variablen Induktivitätseinrichtung (130, 540) anzuzeigen, von dem Zustand mit höherer Induktivität in den Zustand mit niedrigerer Induktivität in Reaktion auf die erfasste Ausgangsspannung zu schalten.

11. Leistungswandler nach Anspruch 10, wobei die Steuerschaltung (120, 520) ferner einen zweiten Komparator (B103, 8503) aufweist, wobei der zweite Komparator ausgebildet ist, eine Spannung an dem Ausgang zu erfassen und der variablen Induktivitätseinrichtung (130, 540) anzuzeigen, von dem Zustand mit niedrigerer Induktivität in den Zustand mit höherer Induktivität in Reaktion auf die erfasste Ausgangsspannung zu schalten.

12. Leistungswandler nach Anspruch 11, der ferner eine Pulsbreitenmodulationssteuerung (506) aufweist, die mit dem Schalter (S503) verbunden ist, wobei die Pulsbreitenmodulationssteuerung (506) ausgebildet ist, dem Schalter (S503) anzuzeigen, die variable Induktivitätseinrichtung (540) von dem Zustand mit niedrigerer Induktivität in den Zustand mit höherer Induktivität und umgekehrt zu schalten.

13. Leistungswandler nach einem der Ansprüche 1 bis 12, der ferner umfasst:

eine Schaltereinrichtung (M101, M102), die mit der variablen Induktivitätseinrichtung (130) verbunden ist, wobei die Schaltereinrichtung einen ersten Zustand und einen zweiten Zustand aufweist, wobei die Schaltereinrichtung ausgebildet ist, ein Zuführen von Eingangsleistung zu der variablen Induktivitätseinrichtung zu ermöglichen, wenn sie in dem ersten Zustand ist, und wobei die Schaltereinrichtung ausgebildet ist, das Zuführen von Eingangsleistung zu der variablen Induktivitätseinrichtung zu unterbinden, wenn sie in dem zweiten Zustand ist; und

eine Pulsbreitenmodulationssteuerung (106), die mit der Schaltereinrichtung (M101, M102) verbunden ist, wobei die Pulsbreitenmodulationssteuerung (106) ausgebildet, der Schaltereinrichtung anzuzeigen, von dem ersten Zustand in den zweiten Zustand und umgekehrt umzuschalten.

14. Leistungswandler nach Anspruch 13, der ferner eine Einrichtung (IC403, IC404) umfasst, die ausgebildet ist, der variablen induktivitätseinrichtung (130, 430) anzuzeigen, von dem Zustand mit höherer Induktivität in den Zustand mit niedrigerer Induktivität umzuschalten, wenn die Schaltereinrichtung (M401, M402) sich in dem ersten Zustand befindet, wobei die Einrichtung (IC403, IC404) ferner ausgebildet ist, der variablen Induktivitätseinrichtung anzuzeigen, von dem Zustand mit niedrigerer Induktivität in den Zustand mit höherer Induktivität umzuschalten, wenn sich die Schaltereinrichtung (M401, M402) in dem zweiten Zustand befindet.

15. Leistungswandler nach Anspruch 1, wobei die variable Induktivitätseinrichtung (130) umfasst:

ein erstes induktives Element (L101);

einen ersten Transformator (T101) mit mehreren Wicklungen (W101, W102, W103), die magnetisch miteinander gekoppelt sind, wobei der Transformator (T101) eine erste Wicklung (W101), die mit dem ersten induktiven Element (L101) gekoppelt ist, eine zweite Wicklung (W103) und eine dritte Wicklung (W103) aufweist;

eine Spannungsquelle (Vi101);

einen ersten Schalter (S104), der mit der zweiten Wicklung (W102) gekoppelt und ausgebildet ist, Spannung von der Spannungsquelle (Vi101) zu der zweiten Wicklung (W102) zu führen;

einen zweiten Schalter (S103), der mit der dritten Wicklung (W103) gekoppelt und ausgebildet ist, Spannung von der Spannungsquelle (Vi101) zu der dritten Wicklung (W103) zu führen;

wobei die Steuerschaltung (120) umfasst:

eine erste Steuerschaltung (B102), die ausgebildet ist, den ersten Schalter (S104) zu veranlassen, die Spannung von der Spannungsquelle (Vi101) zu der zweiten Wicklung (W102) zu führen;

eine zweite Steuerschaltung (B103), die ausgebildet ist, den zweiten Schalter (S103) zu veranlassen, die Spannung von der Spannungsquelle (Vi101) zu der dritten Wicklung (W103) zu führen; und

wobei der Leistungswandler ferner umfasst:

einen ersten Knotenpunkt, der Schaltspannungspulse bereitstellt;

eine Einheit, die das erste induktive Element (L101) und den ersten Transformator (T101) umfasst und die mit dem ersten Knoten, der die Schaltspannungspulse bereitstellt, gekoppelt ist;

einen Ausgangskondensator (C101), der mit der Einheit und einem Rückführknoten des Wandlers verbunden ist;

Ausgangsanschlüsse, die mit dem Ausgangskondensator (C101) zum Anschluss einer Last (107) verbunden sind; und

einer Überspannungsschutzschaltung, die ausgebildet ist, den ersten und den zweiten Schalter (S104, S103) vor einer Beaufschlagung mit Überspannungen zu schützen.

16. Leistungswandler nach Anspruch 15, der ferner eine Einrichtung (B101, B102, B103) zum Überwachen der Wandleriastspannung an den Ausgangsanschlüssen aufweist; und wobei die erste Steuerschaltung (B102) ausgebildet ist, den ersten Schalter (S104) zu veranlassen, die Spannung von der Spannungsquelle (Vi101) zu der zweiten Wicklung (W102) zu führen, wenn die Lastspannung unter den ersten Spannungspegel abfällt, wobei die erste Steuerschaltung (B102) ausgebildet ist, den ersten Schalter (S104) zu veranlassen, die Spannungsquelle (Vi101) von der zweiten Wicklung (W102) zu trennen, wenn die Lastspannung über den zweiten Spannungspegel ansteigt; und wobei die zweite Steuerschaltung (B103) ausgebildet ist, den zweiten Schalter (S103) zu veranlassen, die Spannungsquelle (Vi101) mit der dritten Wicklung (W103) zu verbinden, wenn die Lastspannung über den dritten Spannungspegel steigt, wobei die zweite Steuerschaltung (B103) ferner ausgebildet ist, den zweiten Schalter (S103) zu veranlassen, die Spannungsquelle (Vi101) von der dritten Wicklung (W103) zu trennen, wenn die Lastspannung unter den vierten Spannungspegel abfällt.

17. Leistungswandler nach Anspruch 1, wobei die variable Induktivitätseinrichtung (230) umfasst:

ein erstes induktives Element (L201);
einen ersten Transformator (T201) mit mehreren Wicklungen, die magnetisch miteinander gekoppelt sind, wobei die Wicklungen eine erste Wicklung (W201), die mit dem ersten induktiven Element (L201) gekoppelt ist, eine zweite Wicklung (W202) und eine dritte Wicklung (W203) aufweisen;
einen ersten Schalter (S204), der mit der zweiten Wicklung (W202) verbunden ist;
einen zweiten Schalter (S203), der mit der dritten Wicklung (W203) verbunden ist;

wobei der Leistungswandler ferner umfasst:

ein Paar an Eingangsanschlüssen (201, 202) zum Anschluss einer Gleichspannungsquelle, wobei der erste der Anschlüsse ein positiver Anschluss und der zweite der Anschlüsse ein negativer Anschluss ist;
einen ersten Knotenpunkt, der Schaltspannungspulse bereitstellt;
eine Einheit, die das erste induktive Element (L201) und den ersten Transformator (T201) enthält und die mit dem ersten Knotenpunkt, der die Schaltspannungspulse liefert, verbunden ist;
einen Ausgangskondensator (C201), der mit der Einheit und einem Rückführknoten des Wandlers verbunden ist;
ein Paar an Ausgangsanschlüssen, wobei der erste der Ausgangsanschlüsse ein positiver Anschluss und der zweite der Ausgangsanschlüsse ein negativer Anschluss ist und wobei diese mit dem Ausgangskondensator (C201) zum Bereitstellen eines Verbindungspunktes für eine Last (207) verbunden sind;
eine Überspannungsschutzschaltung, die ausgebildet ist, den ersten und den zweiten Schalter (S204, S203) vor Beaufschlagung mit Überspannungen zu schützen; und

wobei die Steuerschaltung (220) umfasst:

eine erste Steuerschaltung (B202), die ausgebildet ist, den ersten Schalter (S204) zu veranlassen, die zweite Wicklung (202) mit dem Ausgangskondensator (C201) zu verbinden; und
eine zweite Steuerschaltung (B203), die ausgebildet ist, den zweiten Schalter (S203) zu veranlassen, die dritte Wicklung (W203) mit dem Ausgangskondensator (C201) zu verbinden.

18. Der Leistungswandler nach Anspruch 17, wobei die Überspannungsschutzschaltung umfasst:

eine erste Diode (D304), deren Kathode mit dem positiven Eingangsanschluss (301) und deren Anode mit dem Knotenpunkt verbunden ist, der die zweite Wicklung (W302) mit dem ersten Schalter (S304) verbindet; und
eine zweite Diode (D303), deren Kathode mit dem positiven Eingangsanschluss (301) und deren Anode mit einem Knotenpunkt verbunden ist, der die dritte Wicklung (W303) mit dem zweiten Schalter (S303) verbindet.

19. Leistungswandler nach Anspruch 17, wobei die Überspannungsschutzschaltung umfasst:

eine erste Diode (D404), deren Anode mit einem Knotenpunkt verbunden ist, der das erste induktive Element (L401) mit der ersten Transformatorwicklung (W401) verbindet, und deren Kathode mit dem positiven Einganganschluss (402) verbunden ist; und
eine zweite Diode (D403), deren Anode mit dem negativen Eingangsanschluss (401) und deren Kathode mit einem Knoten verbunden ist, der die zweite Wicklung (W402) mit der dritten Wicklung (W403) verbindet.

20. Leistungswandler nach einem der Ansprüche 17 bis 19, der ferner eine Einrichtung (8201, B202, 8203) zum Überwachen der Wandlerlastspannung an den Ausgangsanschlüssen aufweist; und wobei
die erste Steuerschaltung (B202) ausgebildet ist, den ersten Schalter (S204) zu veranlassen, die zweite Wicklung (W202) mit dem Ausgangskondensator (C201) zu verbinden, wenn die Lastspannung unter den ersten Spannungspegel abfällt, wobei die erste Steuerschaltung (B202) ferner ausgebildet ist, den ersten Schalter (S204) zu veranlassen, die zweite Wicklung (W202) von dem Ausgangskondensator (C201) zu trennen, wenn die Lastspannung über den zweiten Spannungspegel steigt; und
wobei die zweite Steuerschaltung (B203) ausgebildet ist, den zweiten Schalter (S203) zu veranlassen, die dritte Wicklung (W203) mit dem Ausgangskondensator (C201) zu verbinden, wenn die Lastspannung über den dritten Spannungspegel steigt, wobei die zweite Steuerschaltung (B203) ferner ausgebildet ist, den zweiten Schalter (S203) zu veranlassen, die dritte Wicklung (W203) von dem Ausgangskondensator (C201) zu trennen, wenn die Lastspannung unter den vierten Spannungspegel fällt.

21. Leistungswandler nach Anspruch 20, der ferner umfasst:

eine erste Einrichtung (IC404) zum Schalten des ersten Schalters (S404) in einen Ein-Zustand nur dann, wenn eine hohe Pulsspannung an das erste induktive Element (L401) angelegt wird;
eine zweite Einrichtung (IC403) zum Schalten

des zweiten Schalters (S403) in einen Ein-Zustand nur dann, wenn eine geringe Pulsspannung an das erste induktive Element (L401) angelegt wird.

22. Leistungswandler nach Anspruch 1, wobei die variable Induktivitätseinrichtung (540) umfasst:

ein erstes induktives Element (L502), das mit einem ersten Knotenpunkt verbunden ist, der Schaltspannungspulse mit einem hohen Spannungspegel und einem niedrigen Spannungspegel liefert;
ein zweites induktives Element (501), das mit einem ersten Reihenschalter (S503) in Reihe geschaltet ist, wodurch eine Kombination aus induktivem Element und Reihenschalter gebildet wird, wobei die Kombination parallel zu dem ersten induktiven Element (L502) angeordnet ist;

wobei die Steuerschaltung (520) ausgebildet ist, den ersten Reihenschalter (S503) zu veranlassen, das zweite induktive Element (L501) in Reihe zu dem ersten induktiven Element (L502) zu schalten;
wobei der Leistungswandler ferner umfasst:

ein Paar an Eingangsanschlüssen (501, 502) zur Verbindung mit einer Gleichspannungsquelle, wobei der erste der Anschlüsse ein positiver Anschluss und zweite der Anschlüsse ein negativer Anschluss ist;
eine erste Diode, deren Kathode mit dem positiven Eingangsanschluss und deren Anode mit einem Knotenpunkt verbunden ist, der das zweite induktive Element (L501) mit dem ersten Reihenschalter (S503) verbindet;
eine zweite Diode, deren Anode mit dem negativen Eingangsanschluss und deren Kathode mit einem Knotenpunkt verbunden ist, der das zweite induktive Element (L501) mit dem ersten Reihenschalter (S503) verbindet;
einen Ausgangskondensator (C501), der mit dem ersten induktiven Element (L502) und einem Rückführknotenpunkt des Wandlers verbunden ist;
einem Paar an Ausgangsanschlüssen, die mit dem Ausgangskondensator (C501) zum Bereitstellen eines Anschlusspunktes für eine Last (507) verbunden sind; und
eine Überspannungsschutzschaltung, die ausgebildet ist, den ersten Schalter vor einer Beaufschlagung mit einer Überspannung zu schützen.

23. Leistungswandler nach Anspruch 22, der ferner eine Einrichtung (B501, B502, B503) zum Überwachen der Wandlerlastspannung an den Ausgangsanschlüssen aufweist; und wobei
die Steuerschaltung (525) ausgebildet ist, den ersten Reihenschalter (S503) zu veranlassen, das zweite induktive Element (L501) parallel zu dem ersten induktiven Element (L502) zu schalten, wenn die Lastspannung unter den ersten Spannungspegel fällt, wobei die Steuerschaltung (525) ferner ausgebildet ist, den ersten Reihenschalter (S503) zu veranlassen, das zweite induktive Element (L501) von dem ersten induktiven Element (L502) zu trennen, wenn die Lastspannung über den zweiten Spannungsspiegel steigt;
wobei die Steuerschaltung (525) ferner ausgebildet ist, den ersten Reihenschalter (S503) zu veranlassen, das zweite induktive Element (L501) parallel mit dem ersten induktiven Element (L502) zu verbinden, wenn die Lastspannung über den dritten Spannungspegel steigt, wobei die Steuerschaltung (525) ferner ausgebildet ist, den ersten Reihenschalter (S503) zu veranlassen, das zweite induktive Element (L501) von dem ersten induktiven Element (L502) zu trennen, wenn die Lastspannung unter den vierten Spannungspegel sinkt.

24. Leistungswandler nach Anspruch 23, der ferner umfasst:

eine erste Einrichtung (IC504) zum Schalten des ersten Reihenschalters (S503) in einen Ein-Zustand nur dann, wenn eine hohe Pulsspannung an das erste induktive Element (L502) angelegt wird; und
eine zweite Einrichtung (IC503) zum Schalten des Reihenschalters (S503) in einen AusZustand nur dann, wenn eine geringe Pulsspannung an das erste induktive Element (L502) angelegt wird.

25. Vorrichtung mit einem Leistungswandler nach einem der Ansprüche 1 bis 24 und einer elektrischen Last, die mit dem Ausgang gekoppelt ist, um die geregelte Ausgangsleistung zu empfangen.

Revendications

1. Convertisseur de puissance comprenant :

une entrée (101, 102) destinée à recevoir la puissance d'entrée ;
une sortie destinée à fournir la puissance de sortie régulée ;
un dispositif d'inductance variable (130, 540) couplé entre l'entrée et la sortie, ledit dispositif d'inductance variable (130, 540) possédant un état d'inductance supérieure et un état d'inductance inférieure, ledit dispositif d'inductance variable étant contrôlable pour commuter entre le-

dit état d'inductance supérieure et ledit état d'inductance inférieure ; et
un circuit de commande (120, 520) utilisable pour détecter la tension à la sortie :

caractérisé en ce que
ledit circuit de commande est utilisable pour indiquer audit dispositif d'inductance variable :

de commuter vers ledit état d'inductance inférieure quand la tension en sortie baisse en dessous d'un premier niveau de tension (V11) ;
de commuter vers ledit état d'inductance supérieure quand la tension en sortie augmente au-dessus d'un second niveau de tension (V12) qui est supérieur audit premier niveau de tension (V11) ;
de commuter vers ledit état d'inductance inférieure quand la tension en sortie augmente au-dessus d'un troisième niveau de tension (V13) ; et
de commuter vers ledit état d'inductance supérieure quand la tension en sortie baisse en dessous d'un quatrième niveau de tension (V14) qui est inférieur audit troisième niveau de tension (V13), moyennant quoi ledit quatrième niveau de tension (V14) est supérieur audit second niveau de tension (V12).

2. Convertisseur de puissance selon la revendication 1 dans lequel ledit dispositif d'inductance variable (130) comprend un composant d'inductance fixe (L101) et un composant d'inductance variable (L140), ledit composant d'inductance variable (L140) étant couplé en série audit composant d'inductance fixe (L101), ledit composant d'inductance variable (L140) comprenant un transformateur (T101) comportant une pluralité d'enroulements (W101, W102, W103).

3. Convertisseur de puissance selon la revendication 2 dans lequel ledit transformateur (T101) comporte trois enroulements (W101, W102, W103).

4. Convertisseur de puissance selon la revendication 2 ou 3 dans lequel un premier enroulement (W101) dudit transformateur (T101) est en série avec ledit composant d'inductance fixe (L101).

5. Convertisseur de puissance selon la revendication 4 comprenant en outre une source d'énergie auxiliaire (Vi101) qui est couplée en série à un second enroulement (W102) dudit transformateur (T101) et à un premier commutateur (S104).

6. Convertisseur de puissance selon la revendication 5 dans lequel ladite source d'énergie auxiliaire (Vi101) est couplée en série à un troisième enroulement (W103) dudit transformateur (T101) et à un second commutateur (S103).

7. Convertisseur de puissance selon la revendication 5 ou 6 dans lequel ladite source d'énergie auxiliaire (Vi101) est couplée à ladite source d'énergie d'entrée.

8. Convertisseur de puissance selon la revendication 5 ou 6 dans lequel ladite source de d'énergie auxiliaire (Vi101) est couplée à ladite sortie.

9. Convertisseur de puissance selon la revendication 1, dans lequel ledit dispositif d'inductance variable (540) comprend :

un élément d'inductance inférieure (L501) ;
un commutateur (S503) couplé en série audit élément d'inductance inférieure (L501) formant ainsi une combinaison en série de commutateur et d'élément d'inductance inférieure (S503, L501) ; et
un élément d'inductance supérieure (L502) couplé en parallèle à ladite combinaison en série de commutateur et d'élément d'inductance inférieure (S503, L501) ;

dans lequel ledit commutateur (S503) est utilisable pour commuter ledit dispositif d'inductance variable (540) entre ledit état d'inductance inférieure et ledit état d'inductance supérieure.

10. Convertisseur de puissance selon l'une quelconque des revendications 1 à 9 dans lequel ledit circuit de commande (120, 520) comprend un premier comparateur (B102, B502), ledit premier comparateur étant utilisable pour détecter la tension à ladite sortie et pour indiquer audit dispositif d'inductance variable (130, 540) de commuter dudit état d'inductance supérieure vers ledit état d'inductance inférieure en réponse à la tension de sortie détectée.

11. Convertisseur de puissance selon la revendication 10 dans lequel ledit circuit de commande (120, 520) comprend en outre un second comparateur (B103, B503), ledit second comparateur étant utilisable pour détecter la tension à ladite sortie et pour indiquer audit dispositif d'inductance variable (130, 540) de commuter dudit état d'inductance inférieure vers ledit état d'inductance supérieure en réponse à la tension de sortie détectée.

12. Convertisseur de puissance selon la revendication 11 comprenant en outre un contrôleur de modulation d'impulsions en durée (506) couplé audit commutateur (S503), ledit contrôleur de modulation d'impulsions en durée (506) étant utilisable pour indiquer audit commutateur (S503) de commuter ledit dispositif d'inductance variable (540) entre ledit état d'inductance inférieure et ledit état d'inductance supérieure.

13. Convertisseur de puissance selon l'une quelconque des revendications 1 à 12, comprenant en outre :

des moyens de commutation (M101, M102) couplés audit dispositif d'inductance variable (130), lesdits moyens de commutation ayant un premier état et un second état, lesdits moyens de commutation étant utilisables pour permettre à la puissance d'entrée d'atteindre ledit dispositif d'inductance variable quand ils sont dans ledit premier état, lesdits moyens de commutation étant utilisables pour faire résister le flux de puissance d'entrée audit dispositif d'inductance variable quand ils sont dans un second état ; et
un contrôleur de modulation d'impulsions en durée (106) couplé auxdits moyens de commutation (M101, M102), ledit contrôleur de modulation d'impulsions en durée (106) étant utilisable pour indiquer auxdits moyens de commutation de commuter entre ledit premier état et ledit second état.

14. Convertisseur de puissance selon la revendication 13 comprenant en outre des moyens (IC403, IC404) utilisables pour indiquer audit dispositif d'inductance variable (130, 540) de commuter dudit état d'inductance supérieure vers ledit état d'inductance inférieure quand lesdits moyens de commutation (M401, M402) sont dans ledit premier état, lesdits moyens (IC403, IC404) étant également utilisables pour indiquer audit dispositif d'inductance variable de commuter dudit état d'inductance inférieure vers ledit état d'inductance supérieure quand lesdits moyens de commutation (M401, M402) sont dans ledit second état.

15. Convertisseur de puissance selon la revendication 1, dans lequel
ledit dispositif d'inductance variable (130) comprend :

une première inductance (L101) ;
un premier transformateur (T101) ayant une pluralité d'enroulements (W101, W102, W103) couplés magnétiquement l'un à l'autre, ledit transformateur (T101) comprenant un premier enroulement (W101) couplé à ladite première inductance (L101), un second enroulement (W102), et un troisième enroulement (W103) ;
une source de tension (Vi101) ;
un premier commutateur (S104) couplé audit second enroulement (W102) et utilisable pour coupler la tension de ladite source de tension (Vi101) audit second enroulement (W102) ;
un second commutateur (S103) couplé audit troisième enroulement (W103) et utilisable pour coupler la tension de ladite source de tension (Vi101) audit troisième enroulement (W103) ;

ledit circuit de commande (120) comprenant :

un premier circuit de commande (B102) utilisable pour faire que ledit premier commutateur (S104) couple ladite tension de ladite source de tension (Vi101) audit second enroulement (W102) ;
un second circuit de commande (B103) utilisable pour faire que ledit second commutateur (S103) couple ladite tension de ladite source de tension (Vi101) audit troisième enroulement (W103) ; et

ledit convertisseur de puissance comprend en outre :

un premier noeud qui fournit des impulsions de tension de commutation ;
une unité, comprenant lesdits première inductance (L101) et premier transformateur (T101), couplée audit premier noeud qui fournit des impulsions de tension de commutation ;
un condensateur de sortie (C101) couplé à ladite unité et à un noeud de retour dudit convertisseur ;
des bornes de sortie couplées audit condensateur de sortie (C101) pour la connexion à une charge (107) ; et
un circuit de protection de surtension utilisable pour protéger ledit premier et ledit second commutateurs (S104, S103) contre une exposition à des surtensions.

16. Convertisseur de puissance selon la revendication 15 comprenant en outre des moyens (B101, B102, B103) pour surveiller la tension de charge du convertisseur auxdites bornes de sortie ; et dans lequel
ledit premier circuit de commande (B102) est utilisable pour faire que ledit premier commutateur (S104) couple ladite tension en provenance de ladite source de tension (Vi101) audit second enroulement (W102) quand ladite tension de charge baisse en dessous dudit premier niveau de tension, ledit premier moyen de commande (B102) étant utilisable pour faire que ledit premier commutateur (S104) découple ladite source de tension (Vi101) dudit second enroulement (W102) quand ladite tension de charge augmente au-dessus dudit second niveau de tension ; et
ledit second circuit de commande (B103) est utilisable pour faire que ledit second commutateur (S103) couple ladite source de tension (Vi101) audit troisième enroulement (W103) quand ladite tension de

charge augmente au-dessus dudit troisième niveau de tension, ledit second moyen de commande (B103) étant en outre utilisable pour faire que ledit second commutateur (S103) découple ladite source de tension (Vi101) dudit troisième enroulement (W103) quand ladite tension de charge baisse en dessous de ladite quatrième tension.

17. Convertisseur de puissance selon la revendication 1, dans lequel
ledit dispositif d'inductance variable (230) comprend :

une première inductance (L201) ;
un premier transformateur (T201) comportant une pluralité d'enroulements magnétiquement couplés l'un à l'autre, lesdits enroulements comprenant un premier enroulement (W201) couplé à ladite première inductance (L201), un second enroulement (W202), et un troisième enroulement (W203) ;
un premier commutateur (S204) couplé audit second enroulement (W202) ;
un second commutateur (S203) couplé audit troisième enroulement (W203) ;

ledit convertisseur de puissance comprend en outre :

une paire de bornes d'entrée (201, 202) pour le raccordement à une source de tension continue, la première desdites bornes étant une borne positive et la seconde desdites bornes étant une borne négative ;
un premier noeud qui fournit des impulsions de tension de commutation ;
une unité, comprenant lesdits première inductance (L201) et premier transformateur (T201), couplée audit premier noeud qui fournit des impulsions de tension de commutation ;
un condensateur de sortie (C201) couplé à ladite unité et à un noeud de retour dudit convertisseur ;
une paire de bornes de sortie, la première desdites bornes de sortie étant une borne positive et la seconde desdites bornes de sortie étant une borne négative, couplée audit condensateur de sortie (C201) pour fournir un point de raccordement pour une charge (207) ; et
un circuit de protection de surtension utilisable pour protéger ledit premier et ledit second commutateurs (S204, 5203) contre une exposition à des surtensions ; et

ledit circuit de commande (220) comprend :

un premier circuit de commande (B202) utilisable pour faire que ledit premier commutateur (S204) couple ledit second enroulement (W202) audit condensateur de sortie (C201) ; et
un second circuit de commande (B203) utilisable pour faire que ledit second commutateur (S203) couple ledit troisième enroulement (W203) audit condensateur de sortie (C201).

18. Convertisseur de puissance selon la revendication 17, dans lequel ledit circuit de protection de surtension comprend :

une première diode (D304) ayant sa cathode couplée à ladite borne d'entrée positive (301) et son anode couplée à un noeud reliant ledit second enroulement (W302) et ledit premier commutateur (S304) ; et
une seconde diode (D303) ayant sa cathode couplée à ladite borne d'entrée positive (301) et son anode couplée à un noeud reliant ledit troisième enroulement (W303) et ledit second commutateur (S303) .

19. Convertisseur de puissance selon la revendication 17 dans lequel ledit circuit de protection de surtension comprend :

une première diode (D404) ayant son anode couplée à un noeud reliant ladite première inductance (L401) et ledit premier enroulement de transformateur (W401) et sa cathode couplée à ladite borne d'entrée positive (402) ; et
une seconde diode (D403) ayant son anode couplée à ladite borne d'entrée négative (401) et sa cathode couplée à un noeud reliant ledit second enroulement (W402) et ledit troisième enroulement (W403).

20. Convertisseur de puissance selon l'une quelconque des revendications 17 à 19 comprenant en outre des moyens (B201, B202, B203) permettant de surveiller la tension de charge du convertisseur auxdites bornes de sortie ; et dans lequel
ledit premier circuit de commande (B202) est opérationnel pour faire que ledit premier commutateur (S204) couple ledit second enroulement (W202) audit condensateur de sortie (C201) quand ladite tension de charge baisse en dessous dudit premier niveau de tension, ledit premier circuit de commande (B202) étant également opérationnel pour faire que ledit premier commutateur (S204) découple ledit second enroulement (W202) dudit condensateur de sortie (C201) quand ladite tension de charge augmente au-dessus dudit second niveau de tension ; et ledit second circuit de commande (B203) est opérationnel pour faire que ledit second commutateur (5203) couple ledit troisième enroulement (W203) audit condensateur de sortie (C201) quand ladite tension de charge augmente au-dessus dudit troi-

sième niveau de tension, ledit second circuit de commande (B203) étant en outre opérationnel pour faire que ledit second commutateur (S203) découple ledit troisième enroulement (W203) dudit condensateur de sortie (C201) quand ladite tension de charge baisse en dessous dudit quatrième niveau de tension.

21. Convertisseur de puissance selon la revendication 20 comprenant en outre :

un premier moyen (IC404) destiné à commuter ledit premier commutateur (S404) dans un état passant seulement si une tension d'impulsion élevée est couplée à ladite première inductance (L401) ; et
un second moyen (IC403) destiné à commuter ledit second commutateur (S403) dans un état passant seulement si une tension d'impulsion faible est couplée à ladite première inductance (L401).

22. Convertisseur de puissance selon la revendication 1, dans lequel
ledit dispositif d'inductance variable (540) comprend :

une première inductance (L502) couplée à un premier noeud qui fournit des impulsions de tension de commutation comprenant un niveau de tension élevé et un niveau de tension faible ;
une seconde inductance (L501) couplée en série à un premier commutateur en série (S503) formant ainsi une combinaison en série de commutateur et d'inductance, ladite combinaison étant couplée en parallèle à ladite première inductance (L502) ;

ledit circuit de commande (520) est utilisable pour faire que ledit premier commutateur en série (S503) couple ladite seconde inductance (L501) en parallèle à ladite première inductance (L502) ; et
ledit convertisseur de puissance comprend en outre :

une paire de bornes d'entrée (501, 502) pour le raccordement à une source de tension continue, la première desdites bornes étant une borne positive et la seconde desdites bornes étant une borne négative ;
une première diode ayant sa cathode couplée à ladite borne d'entrée positive et son anode couplée à un noeud reliant ladite seconde inductance (L501) et ledit premier commutateur en série (S503) ;
une seconde diode ayant son anode couplée à ladite borne d'entrée négative et sa cathode couplée à un noeud reliant ladite seconde inductance (L501) et ledit premier commutateur en série (S503) ;
un condensateur de sortie (501) couplé à ladite première inductance (L502) et à un noeud de retour du convertisseur ;
une paire de bornes de sortie couplée audit condensateur de sortie (C501) pour fournir un point de raccordement pour une charge (507) ; et
un circuit de protection de surtension qui est utilisable pour protéger ledit premier commutateur contre une exposition à une surtension.

23. Convertisseur de puissance selon la revendication 22 comprenant en outre des moyens (B501, B502, B503) pour surveiller la tension de charge du convertisseur auxdites bornes de sortie ; et dans lequel ledit circuit de commande (525) est opérationnel pour faire que ledit premier commutateur en série (S503) couple ladite seconde inductance (L501) en parallèle à ladite première inductance (L502) quand ladite tension de charge baisse en dessous dudit premier niveau de tension, ledit circuit de commande (525) étant en outre opérationnel pour faire que ledit premier commutateur en série (S503) découple ladite seconde inductance (L501) de ladite première inductance (L502) quand ladite tension de charge augmente au-dessus dudit second niveau de tension ;
ledit circuit de commande (525) étant en outre opérationnel pour faire que ledit premier commutateur en série (S503) couple ladite seconde inductance (L501) en parallèle à ladite première inductance (L502) quand ladite tension de charge augmente au-dessus dudit troisième niveau de tension, ledit circuit de commande (525) étant également opérationnel pour faire que ledit premier commutateur en série (S503) découple ladite seconde inductance (L501) de ladite première inductance (L502) quand ladite tension de baisse en dessous dudit quatrième niveau de tension.

24. Convertisseur de puissance selon la revendication 23 comprenant en outre :

un premier moyen (IC504) destiné à commuter ledit premier commutateur en série (S503) dans un état passant seulement si une tension d'impulsion élevée est couplée à ladite première inductance (L502) ; et
un second moyen (IC503) destiné à commuter ledit premier commutateur en série (S503) dans un état bloqué seulement si une tension d'impulsion faible est couplée à ladite première inductance (L502).

25. Dispositif comprenant un convertisseur de puissance selon l'une quelconque des revendications 1 à 24 et une charge électrique couplée à ladite sortie pour recevoir la puissance de sortie régulée.

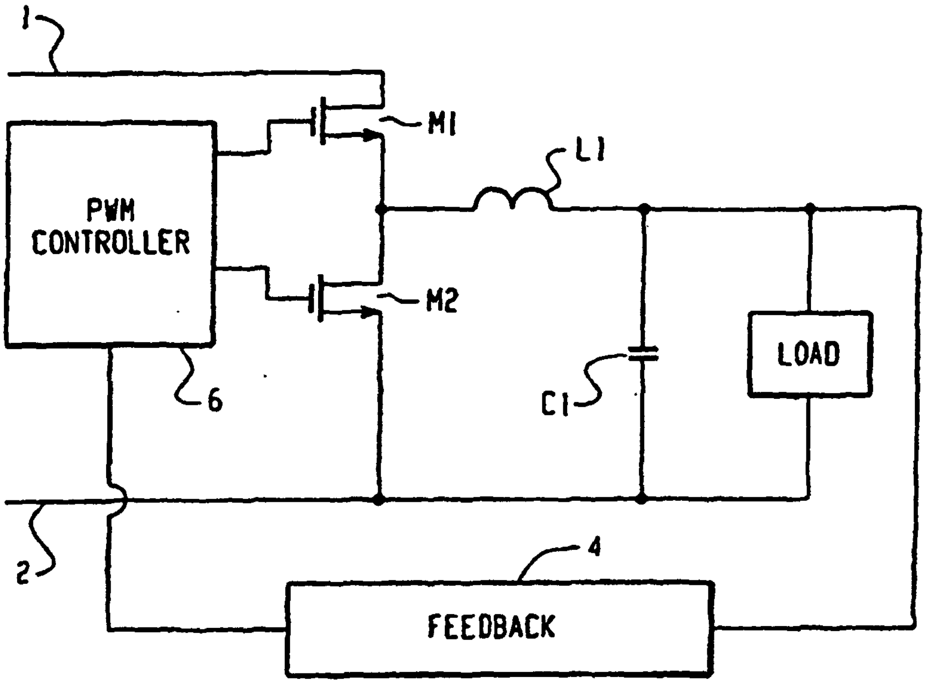
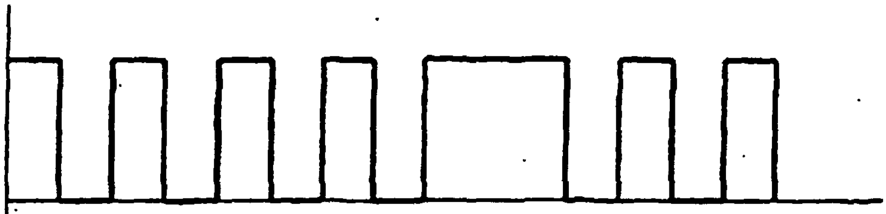
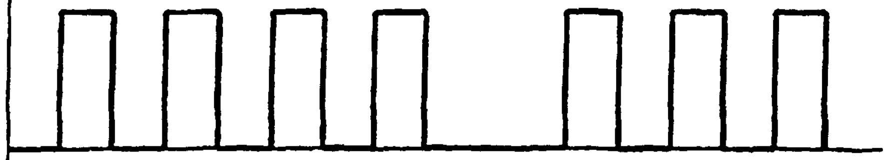


Fig. 1
(PRIOR ART)



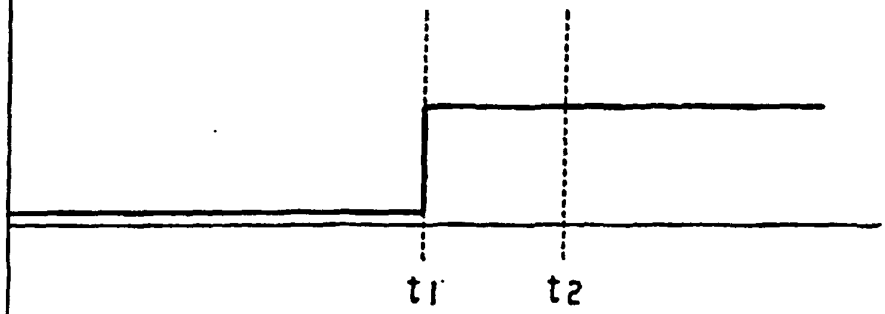
GATE DRIVE OF GATE M1

Fig. 2A



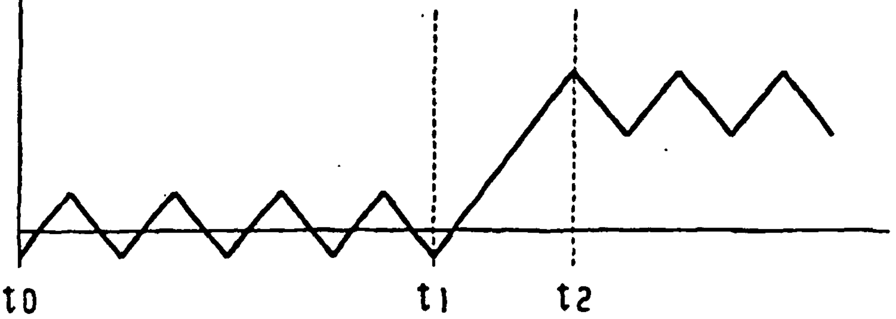
GATE DRIVE OF GATE M2

Fig. 2B



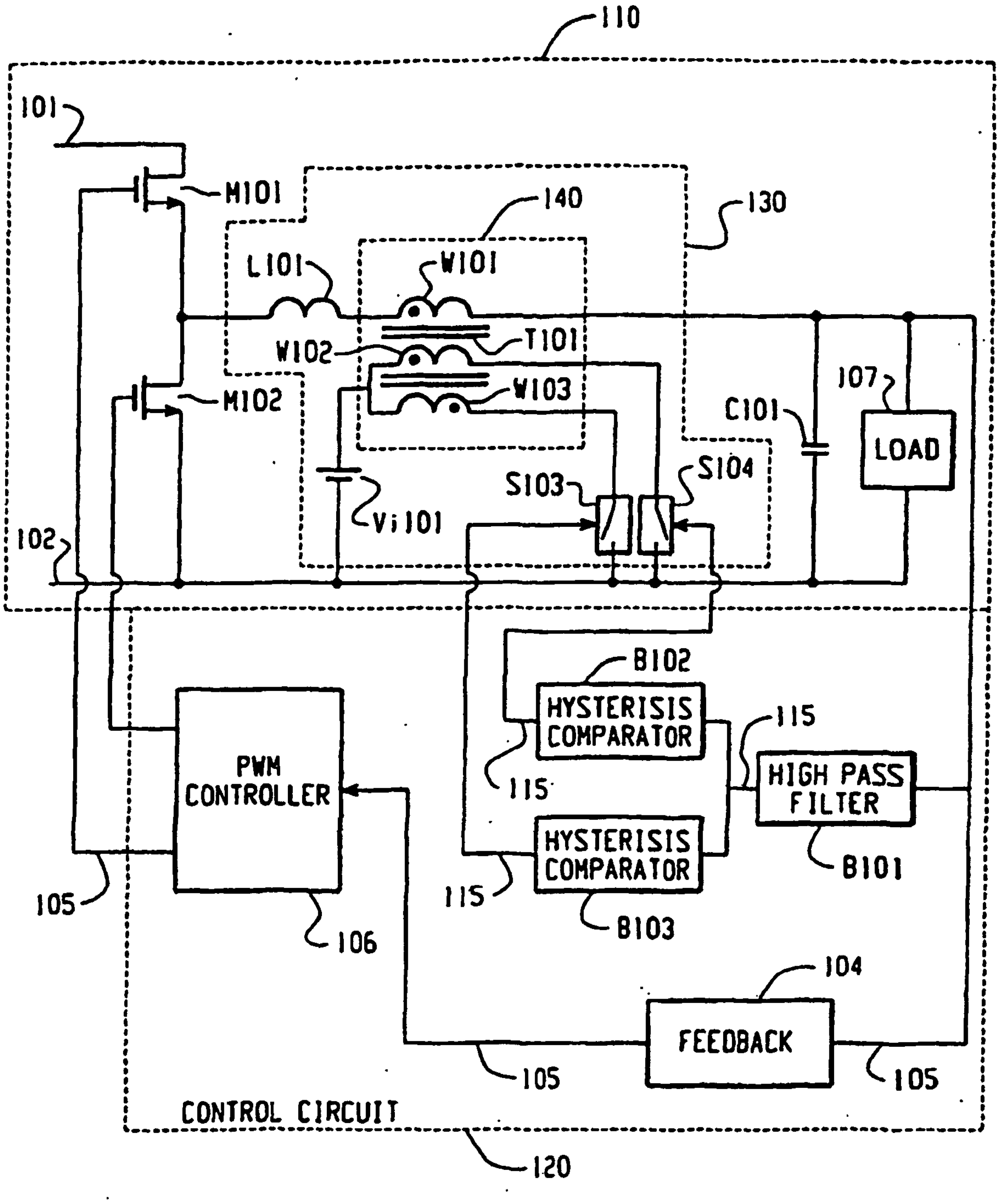
LOAD CURRENT

Fig. 2C



INDUCTOR CURRENT

Fig. 2D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101
M101
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130
L101
W101
T101
W102
W103
M102
C101
107
LOAD
S103
S104
102
Vi101
B102
HYSTERISIS COMPARATOR
115
115
HIGH PASS FILTER
PWM CONTROLLER
115
HYSTERISIS COMPARATOR
B101
105
106
B103
104
FEEDBACK
105
105
CONTROL CIRCUIT
120

Fig. 3

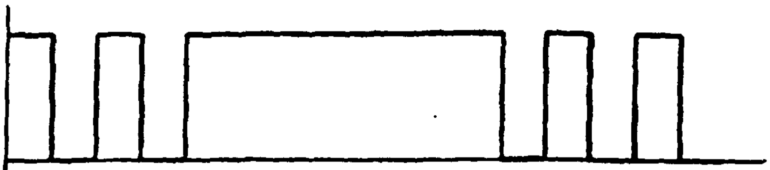


Fig. 4A
GATE DRIVE OF M101

Fig. 4B
GATE DRIVE OF M102

Fig. 4C
LOAD CURRENT

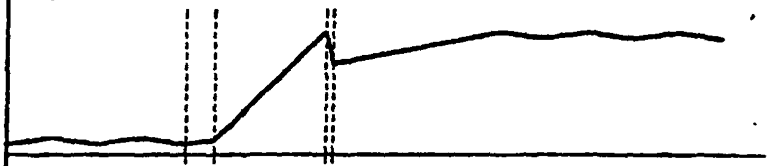


Fig. 4D
L101 CURRENT

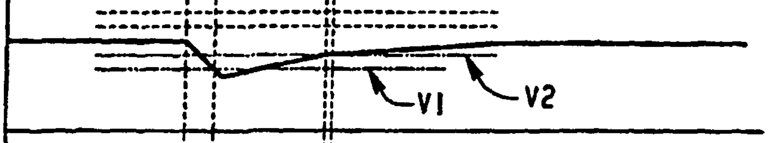


Fig. 4E
O/P VOLTAGE

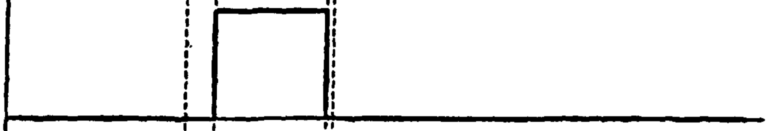


Fig. 4F
S104 DRIVE

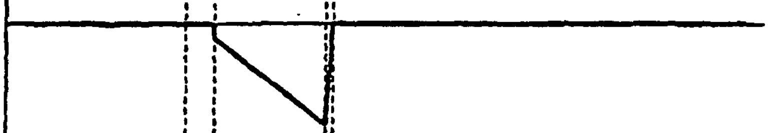


Fig. 4G
M103 CURRENT

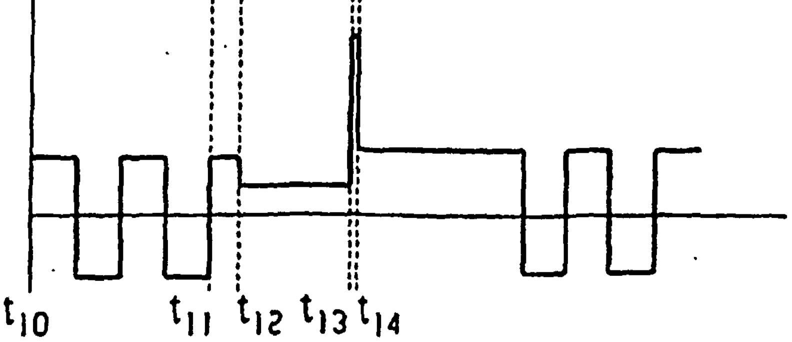


Fig. 4H
M101 VOLTAGE

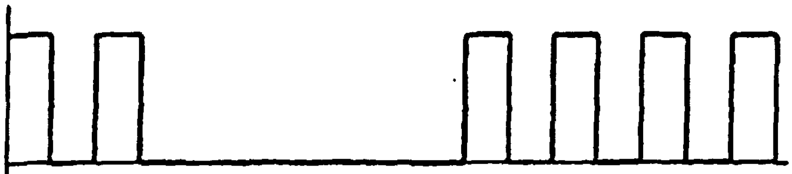


Fig. 5A

GATE DRIVE OF M101

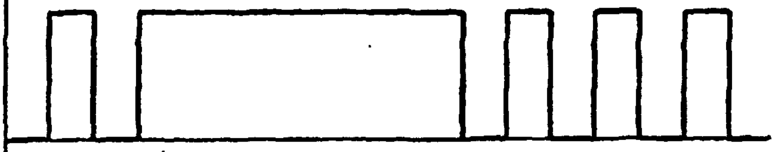


Fig. 5B

GATE DRIVE OF M102

Fig. 5C

LOAD CURRENT

Fig. 5D

L101 CURRENT

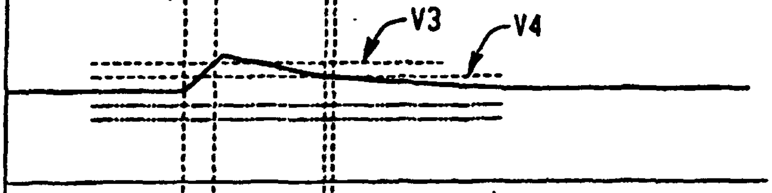


Fig. 5E

O/P VOLTAGE

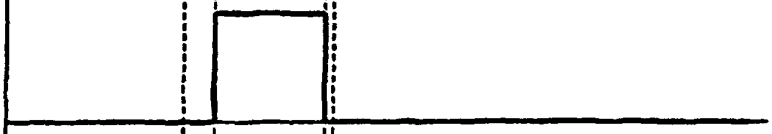


Fig. 5F

S103 DRIVE

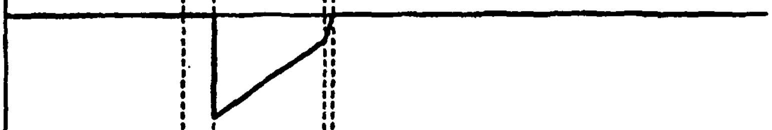


Fig. 5G

W103 CURRENT

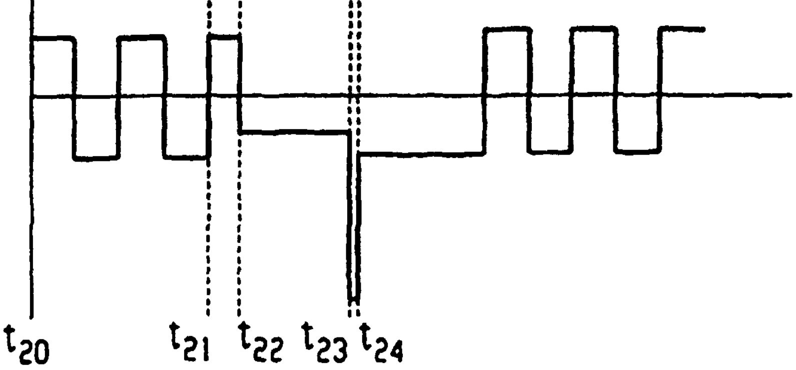
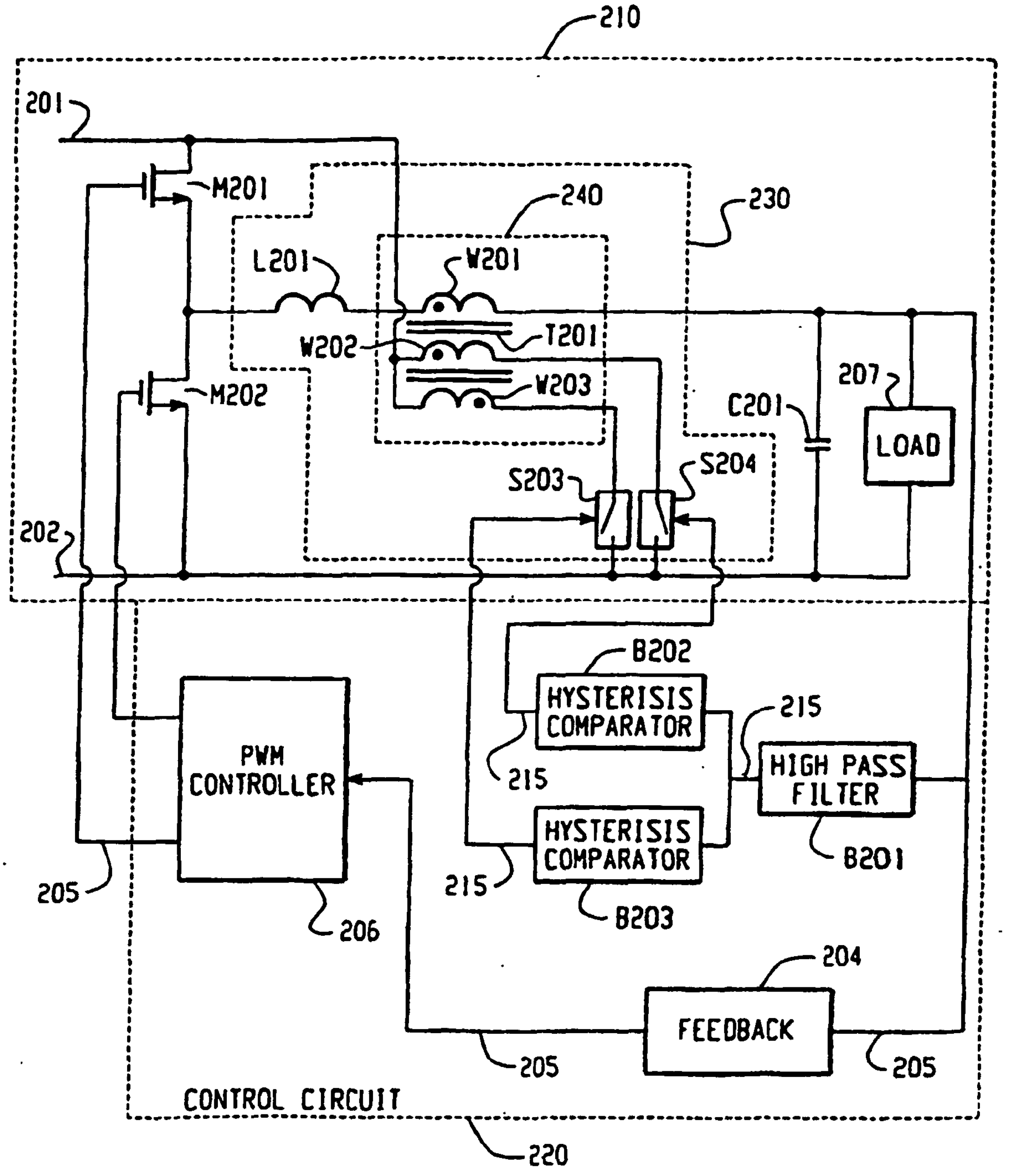


Fig. 5H

W101 VOLTAGE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M201
240
230
L201
W201
W202
T201
M202
W203
207
C201
LOAD
S203
S204
202
B202
HYSTERISIS COMPARATOR
215
215
HIGH PASS FILTER
PWM CONTROLLER
215
HYSTERISIS COMPARATOR
B201
205
B203
206
204
FEEDBACK
205
205
CONTROL CIRCUIT
220

Fig. 6

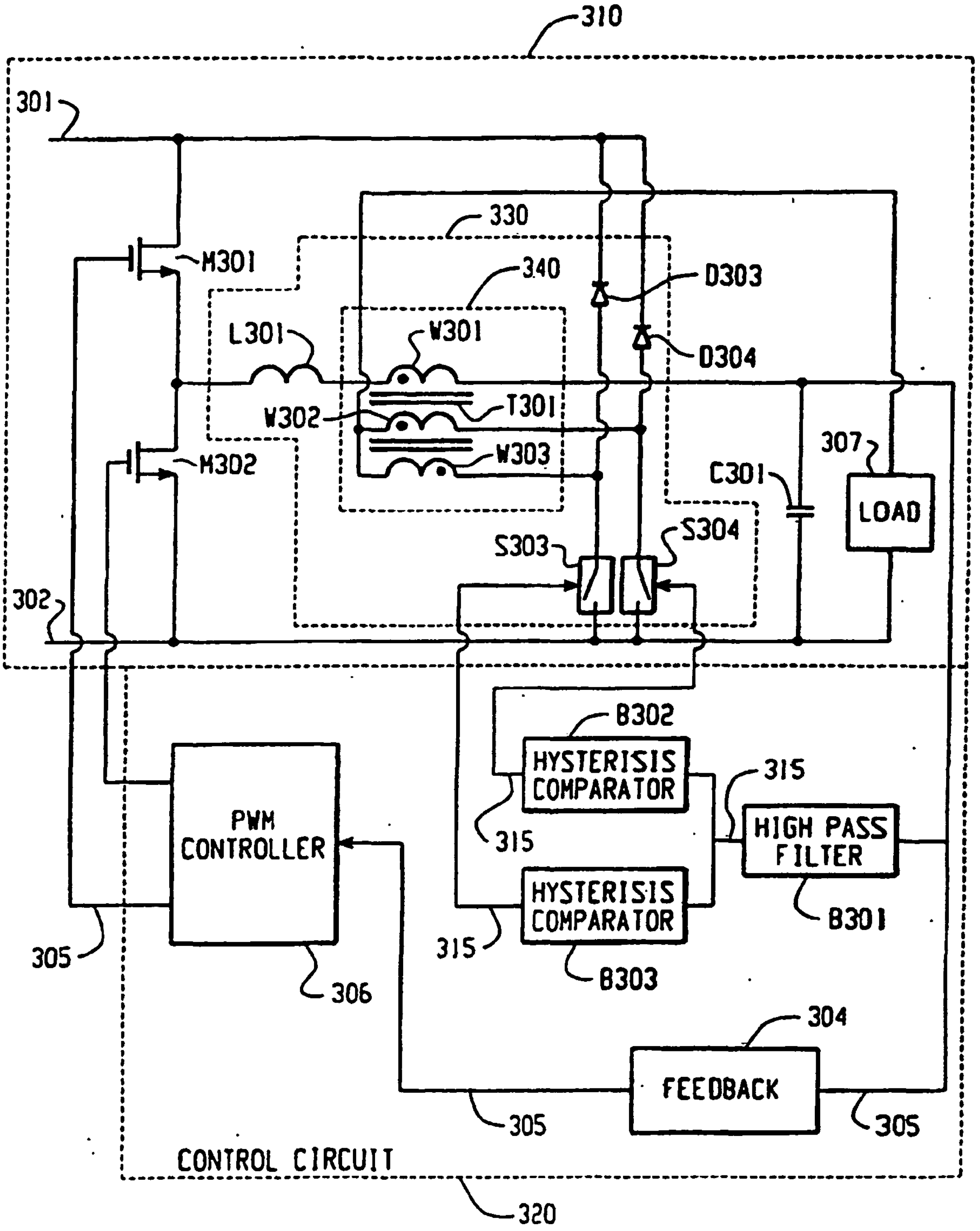
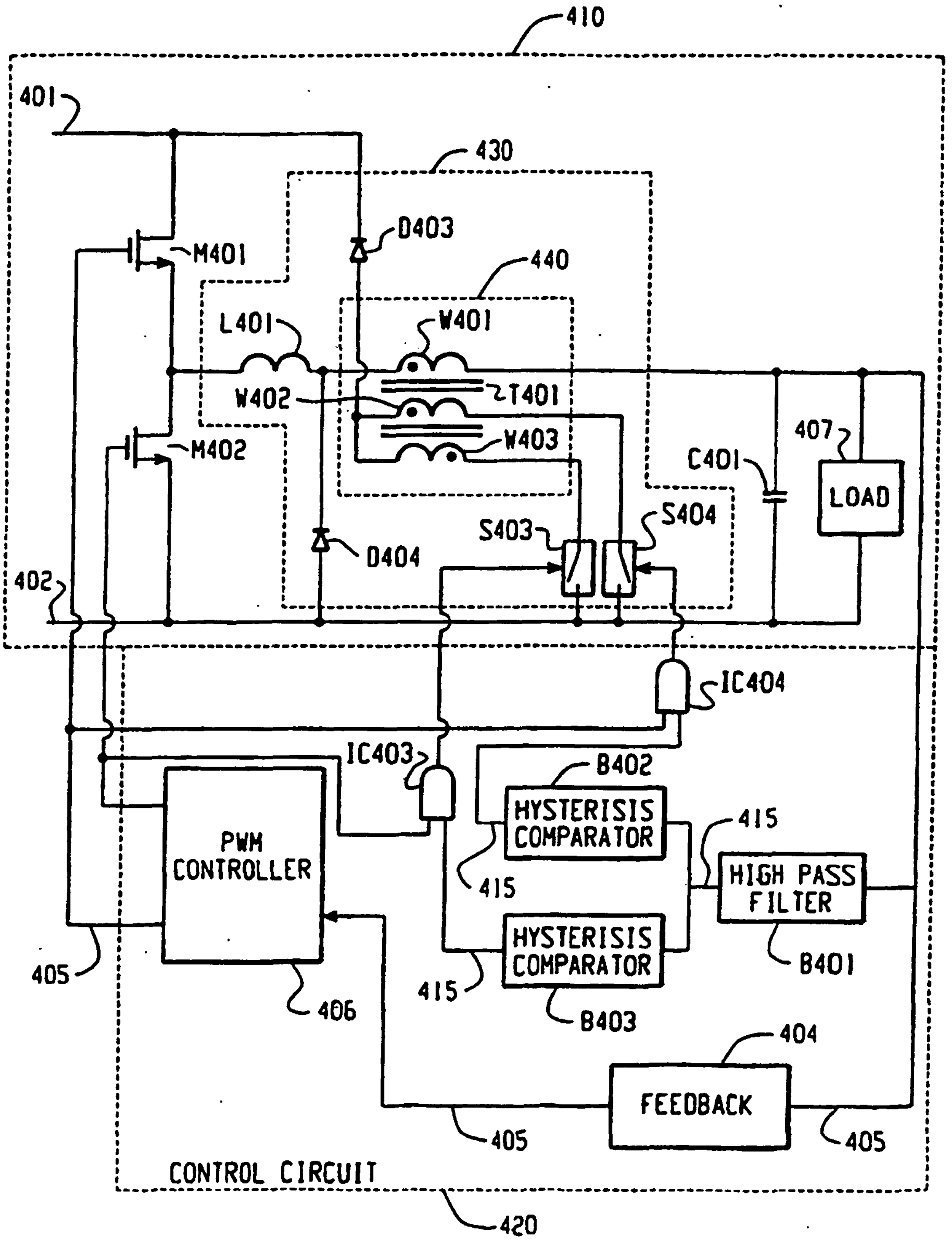

310
301
302
M301
M302
L301
330
340
W301
W302
W303
T301
D303
D304
S303
S304
C301
307
LOAD
B302
HYSTERISIS COMPARATOR
315
315
315
HIGH PASS FILTER
B301
HYSTERISIS COMPARATOR
B303
PWM CONTROLLER
305
306
304
FEEDBACK
305
305
CONTROL CIRCUIT
320

Fig. 7


410
401
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D403
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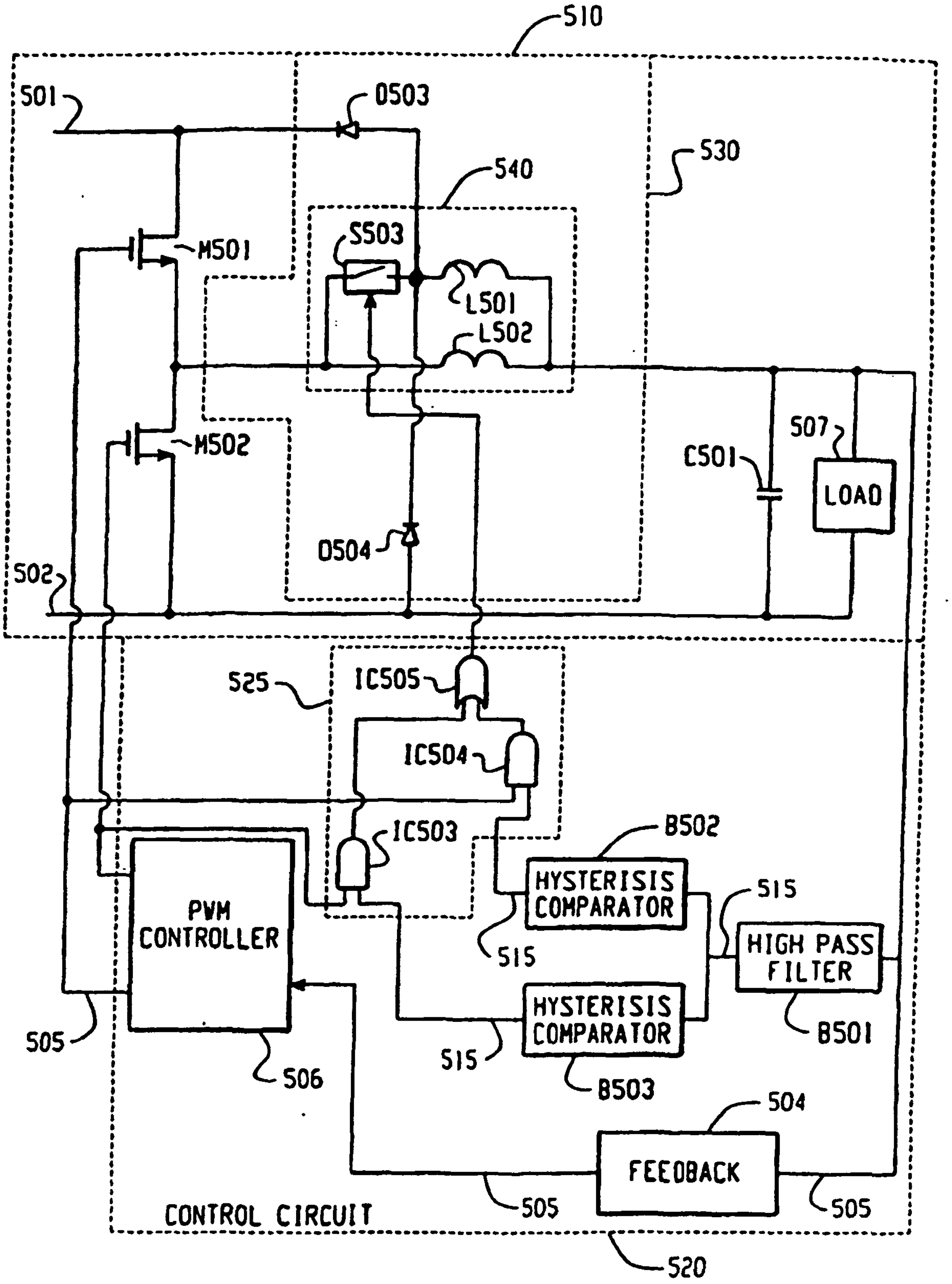
M401
L401
W401
W402
T401
M402
W403
407
C401
LOAD
S403
S404
D404
402
IC404
IC403
B402
HYSTERISIS COMPARATOR
415
PWM CONTROLLER
HIGH PASS FILTER
415
HYSTERISIS COMPARATOR
B401
405
415
406
B403
404
FEEDBACK
405
405
CONTROL CIRCUIT
420

Fig. 8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501
D503
530
540
S503
M501
L501
L502
M502
507
C501
LOAD
D504
502
525
IC505
IC504
IC503
B502
HYSTERISIS COMPARATOR
515
515
515
HIGH PASS FILTER
PWM CONTROLLER
B501
HYSTERISIS COMPARATOR
505
515
506
B503
504
FEEDBACK
505
505
CONTROL CIRCUIT
520

Fig. 9

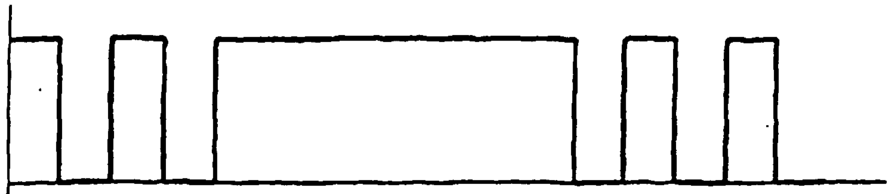

Fig. 10A
GATE DRIVE OF M501

Fig. 10B
GATE DRIVE OF M502

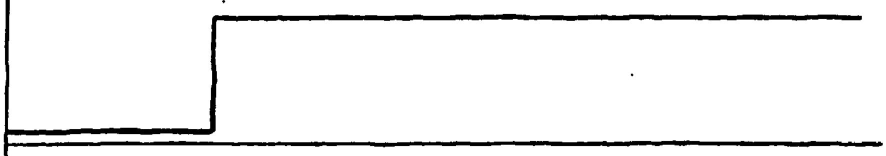

Fig. 10C
LOAD CURRENT

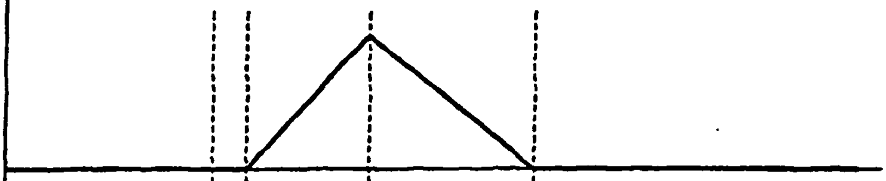

Fig. 10D
L501 CURRENT

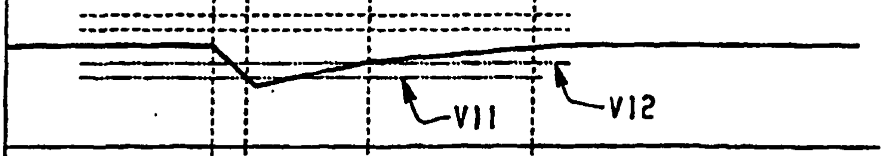

Fig. 10E
O/P VOLTAGE

Fig. 10F
S503 DRIVE

Fig. 10G
L502 CURRENT

Fig. 10H
L501 VOLTAGE

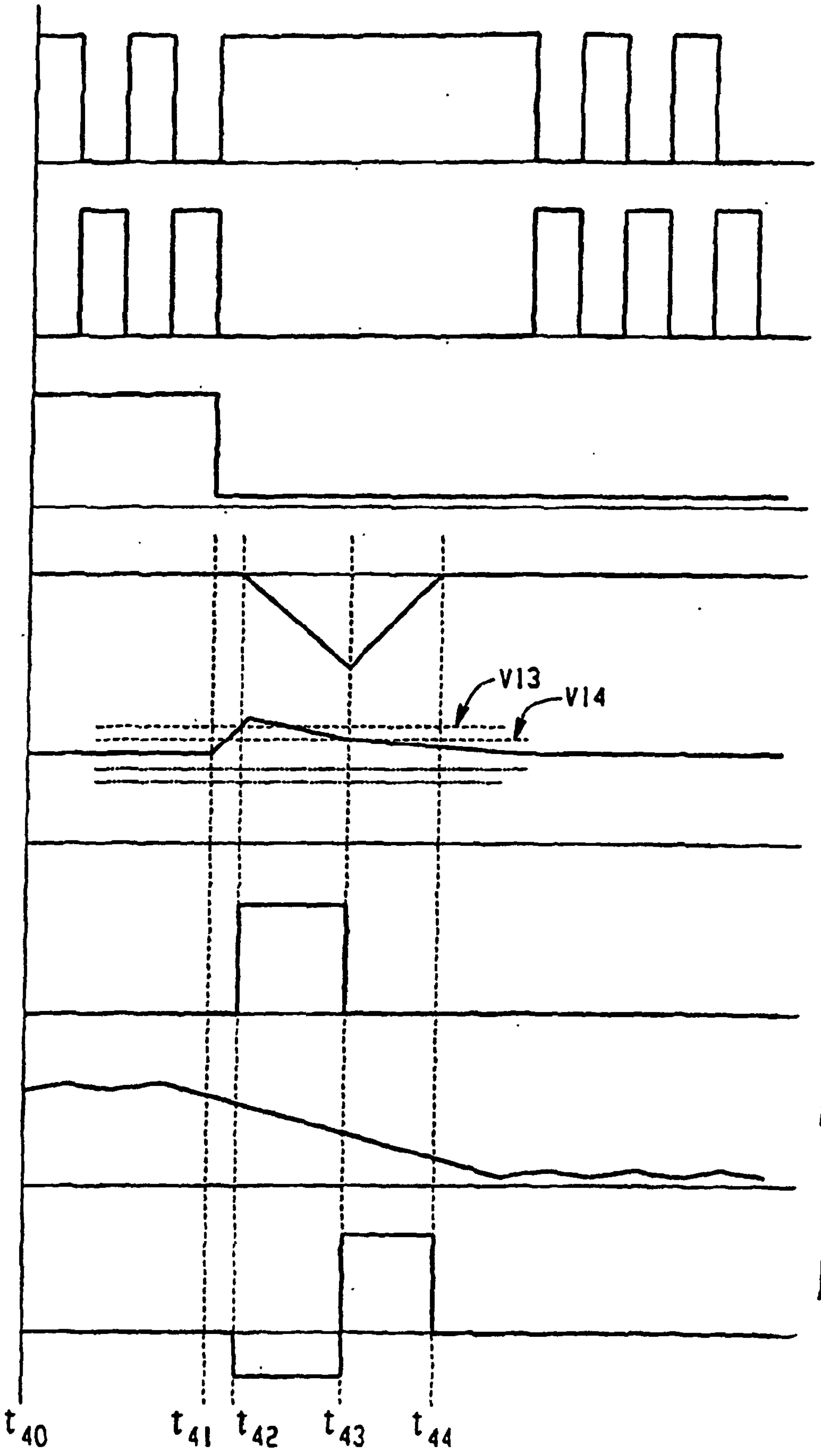

Fig. 11A
GATE DRIVE OF M501

Fig. 11B
GATE DRIVE OF M502

Fig. 11C
LOAD CURRENT

Fig. 11D
L501 CURRENT

Fig. 11E
O/P VOLTAGE

Fig. 11F
S503 DRIVE

Fig. 11G
L502 CURRENT

Fig. 11H
L501 VOLTAGE