



US008014175B2

(12) **United States Patent**
Chang et al.

(10) **Patent No.:** **US 8,014,175 B2**
(45) **Date of Patent:** **Sep. 6, 2011**

(54) **SWITCHING POWER CONVERSION CIRCUIT**

(75) Inventors: **Shih-Hsien Chang**, Taoyuan Hsien (TW); **Chih-Hsuan Lee**, Taoyuan Hsien (TW)

(73) Assignee: **Delta Electronics, Inc.**, Taoyuan Hsien (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 409 days.

(21) Appl. No.: **12/414,512**

(22) Filed: **Mar. 30, 2009**

(65) **Prior Publication Data**

US 2010/0128500 A1 May 27, 2010

(30) **Foreign Application Priority Data**

Nov. 26, 2008 (TW) 97145788 A

(51) **Int. Cl.**
H02M 3/335 (2006.01)
H02M 7/44 (2006.01)

(52) **U.S. Cl.** **363/20**; 363/21.01; 363/21.09;
363/21.17; 363/97; 323/299

(58) **Field of Classification Search** 363/20,
363/21.01, 21.04, 21.09, 21.12, 21.17, 95,
363/97; 323/299, 301

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,289,360	A *	2/1994	Canova		363/21.02
6,717,827	B2 *	4/2004	Ota		363/21.12
2003/0117818	A1 *	6/2003	Ota		363/47
2008/0278138	A1 *	11/2008	Wei		323/318

* cited by examiner

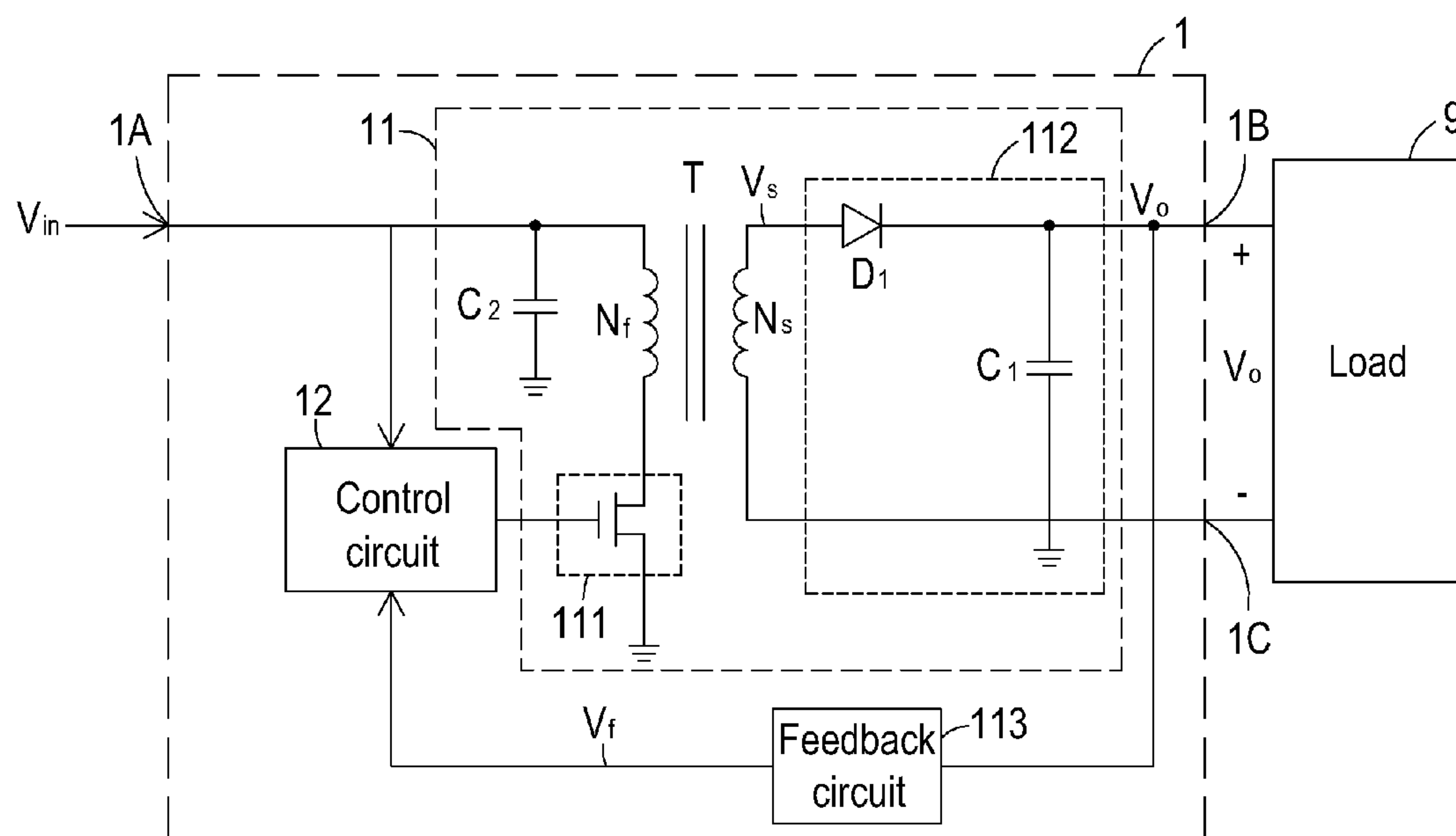
Primary Examiner — Bao Q Vu

(74) *Attorney, Agent, or Firm* — Kirton & McConkie; Evan R. Witt

(57) **ABSTRACT**

A switching power conversion circuit includes a power circuit, a feedback circuit and a control circuit. The power circuit includes a switching circuit and a first magnetic element. The first magnetic element generates a magnetic flux change by alternately conducting or shutting off the switching circuit, so that an input voltage is converted into the output voltage by the power circuit. The feedback circuit generates a feedback signal according to the output voltage. The control circuit is used for controlling an on duration and an off duration of the switching circuit, thereby maintaining the output voltage at a rated voltage. The off duration of the switching circuit is maintained at a constant interval under control of the control circuit. The on duration of the switching circuit is adjusted to be a specified interval smaller than a maximum on duration according to the magnitude of the input voltage.

20 Claims, 8 Drawing Sheets



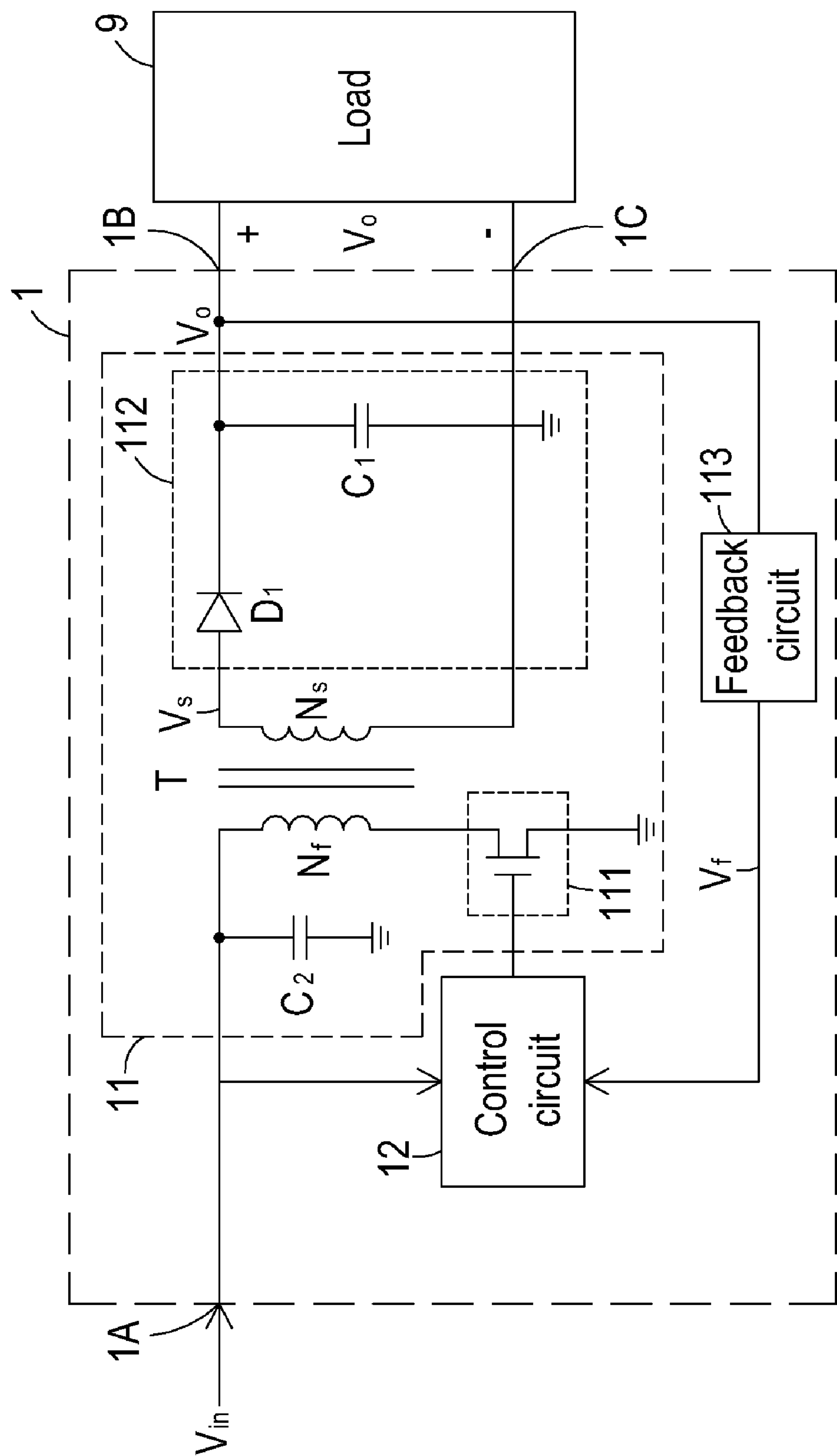


FIG. 1

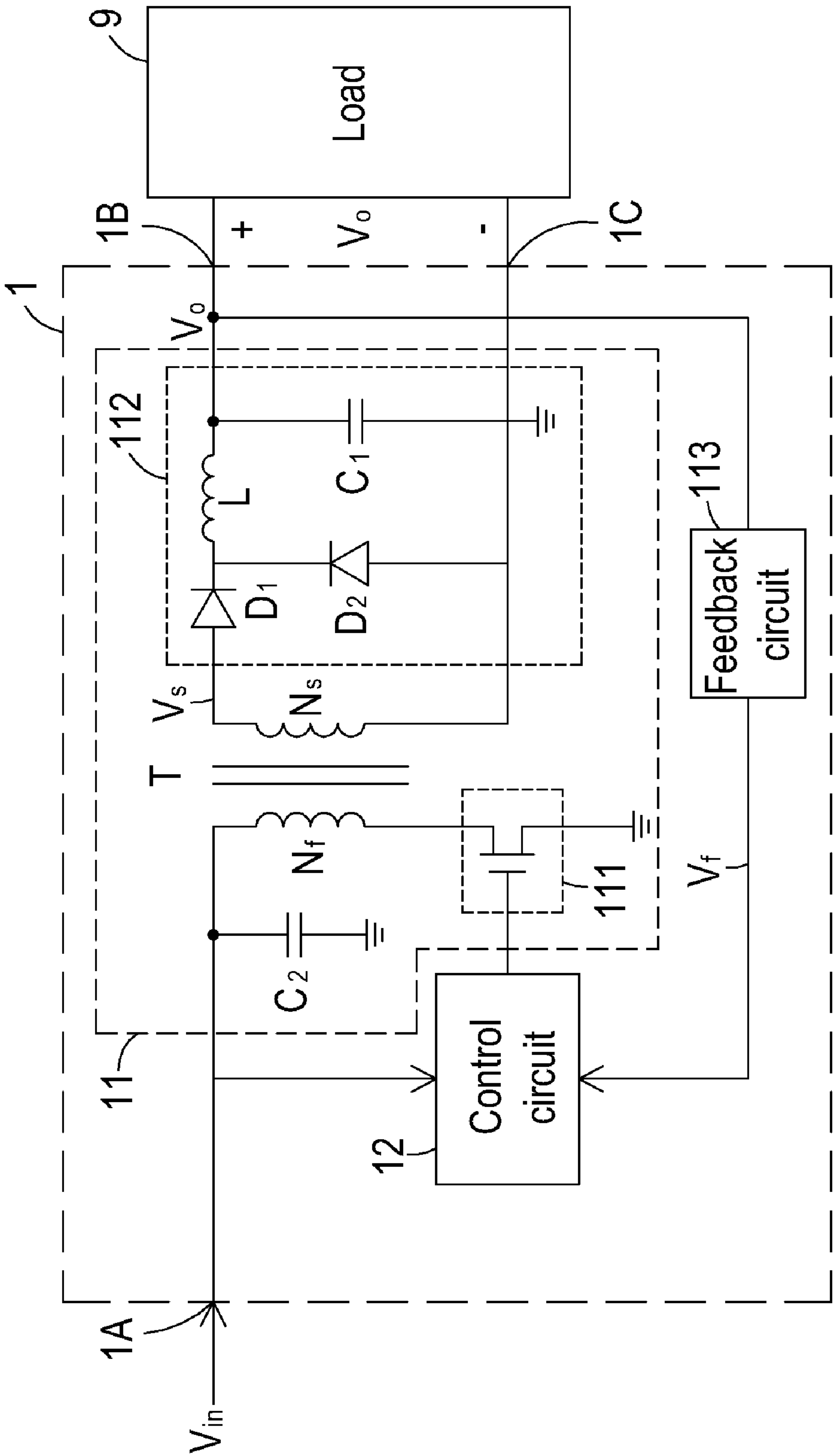


FIG. 2

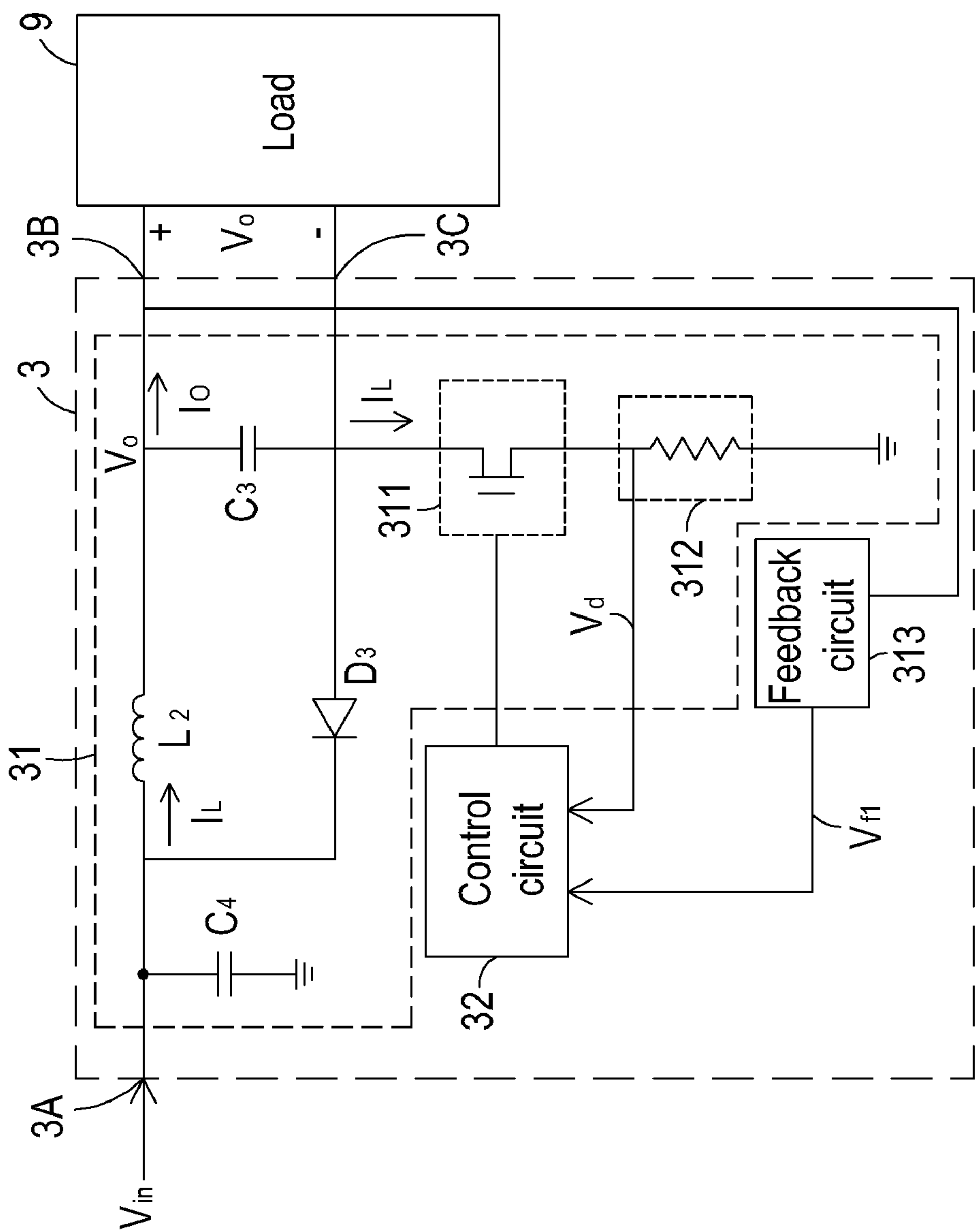


FIG. 3

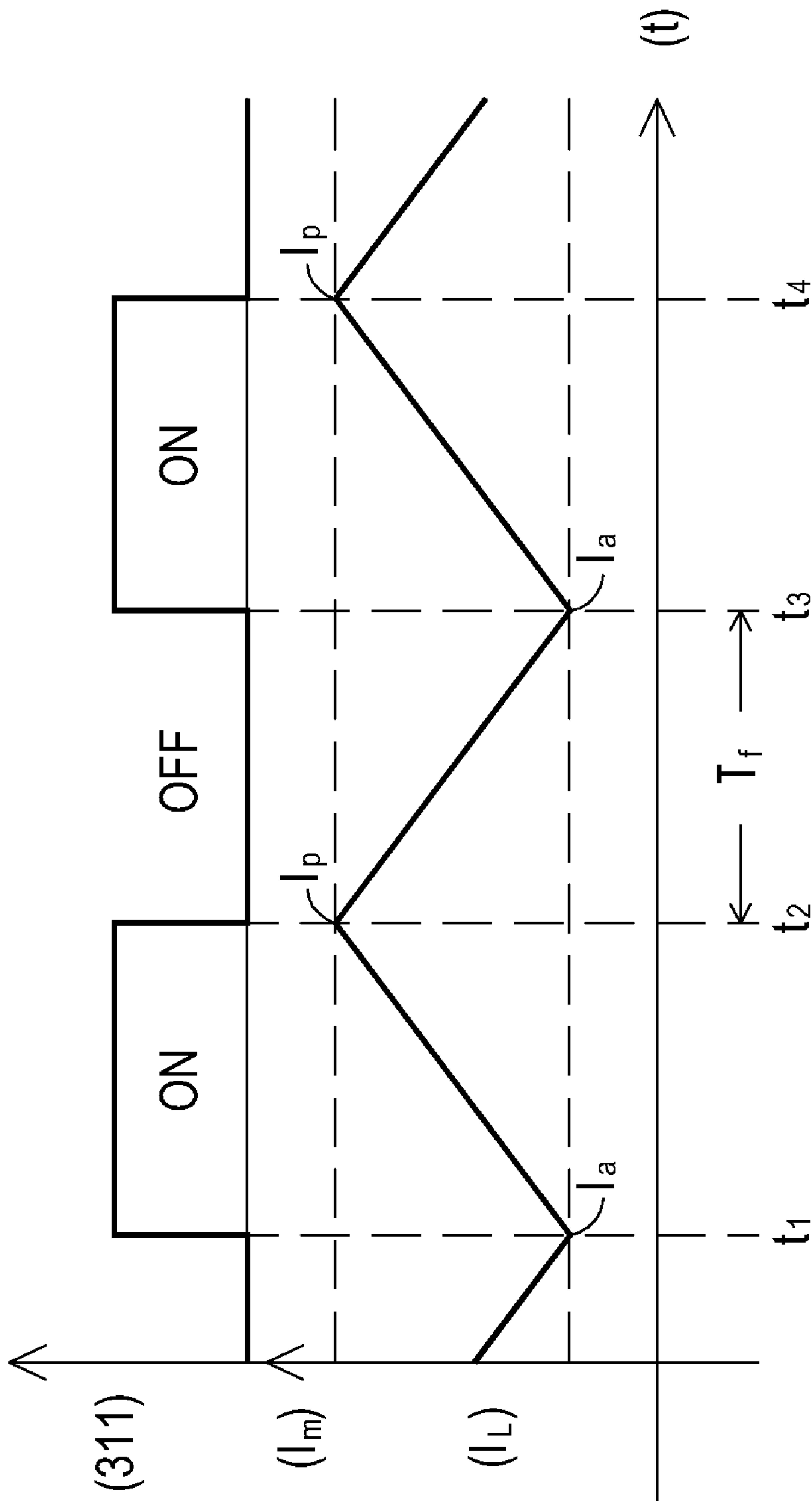


FIG. 4

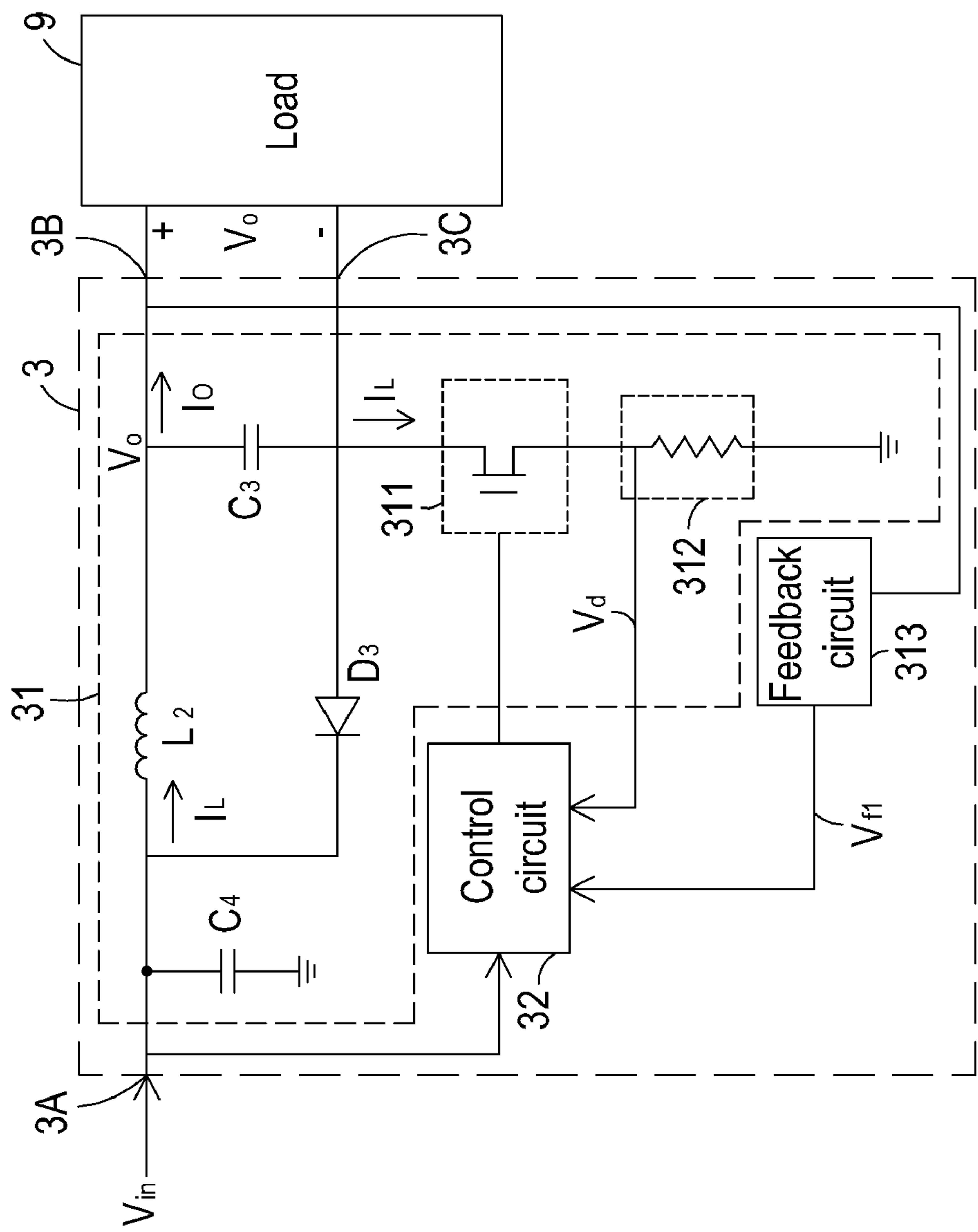


FIG. 5

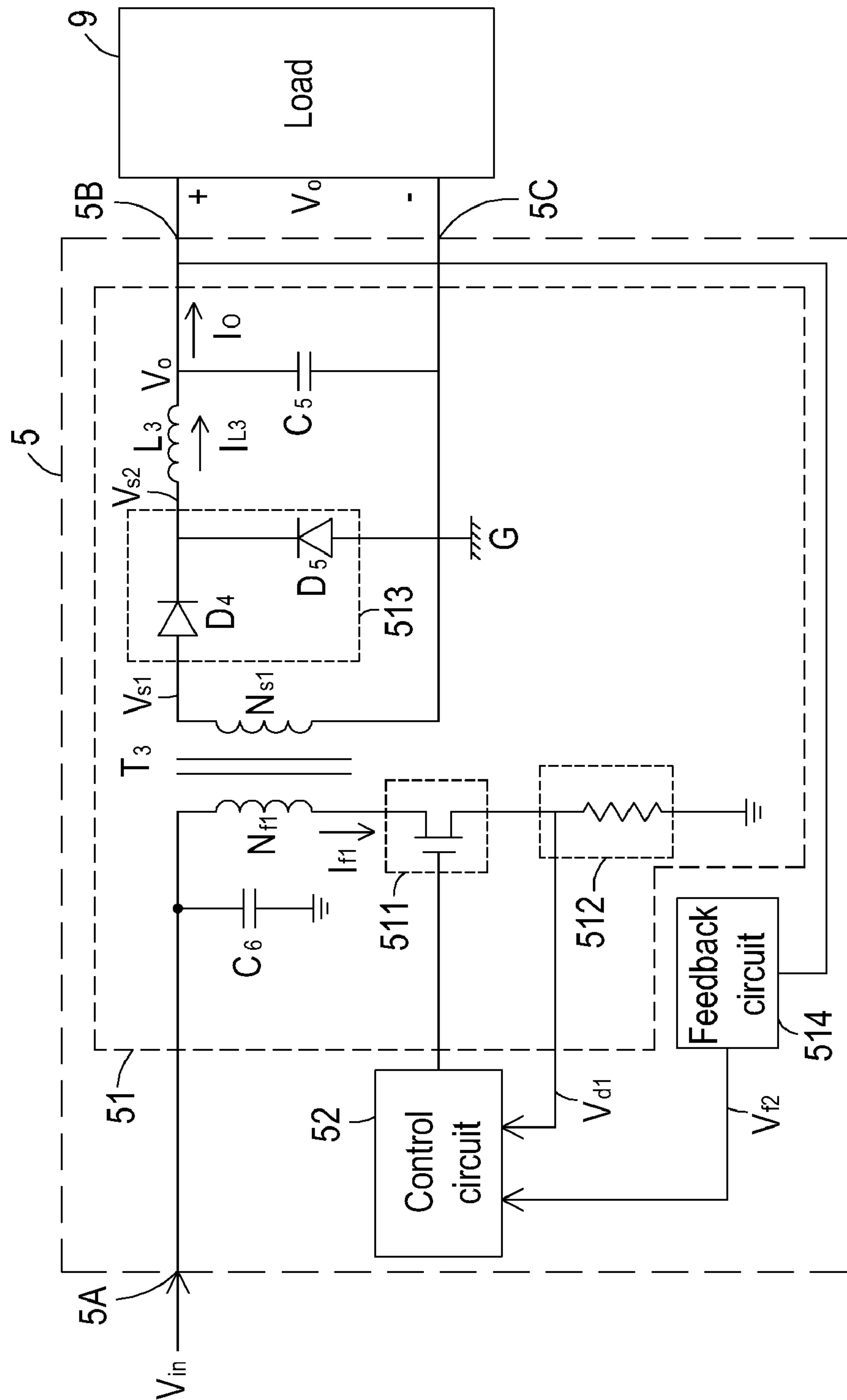


Fig. 6

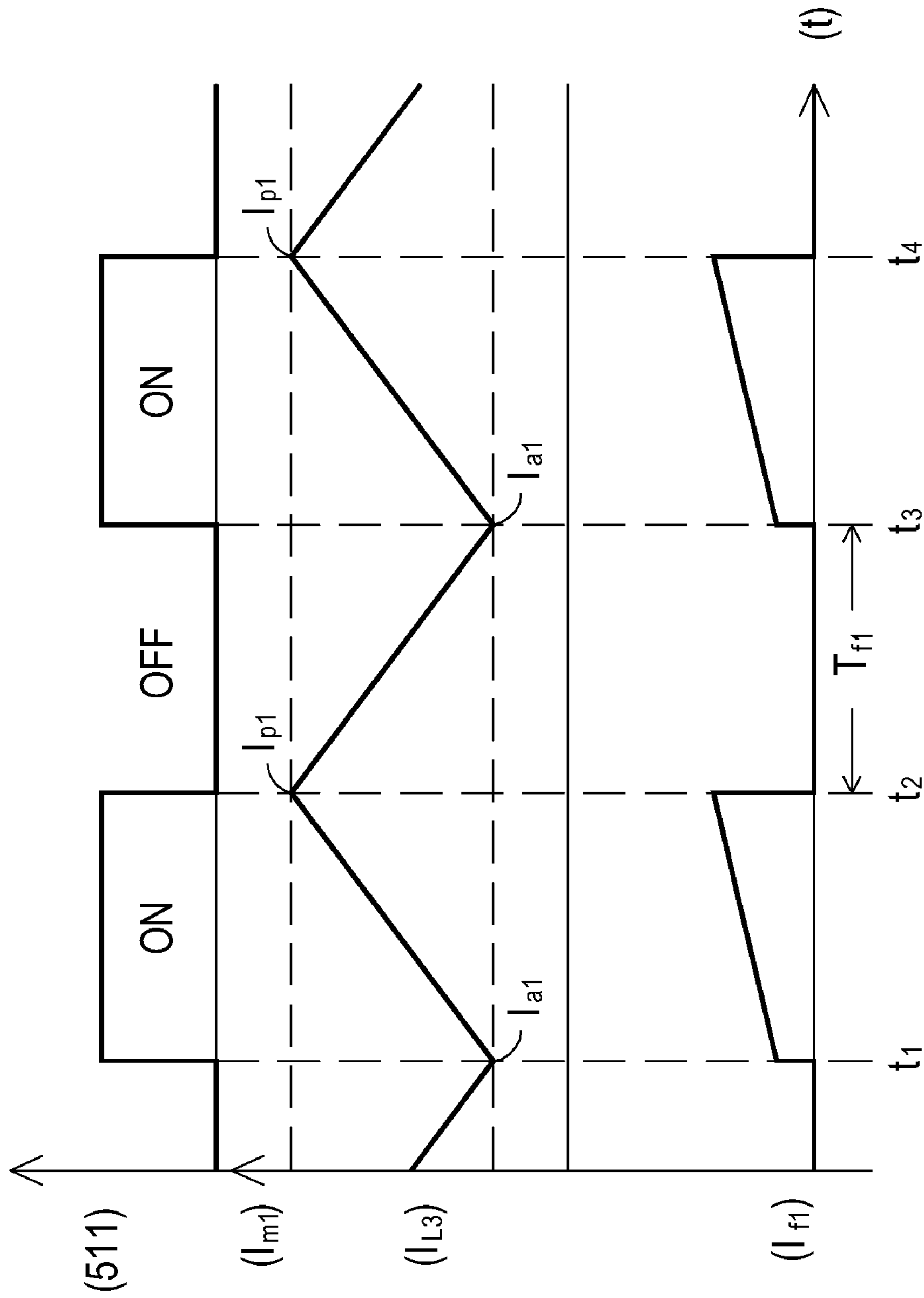


FIG. 7

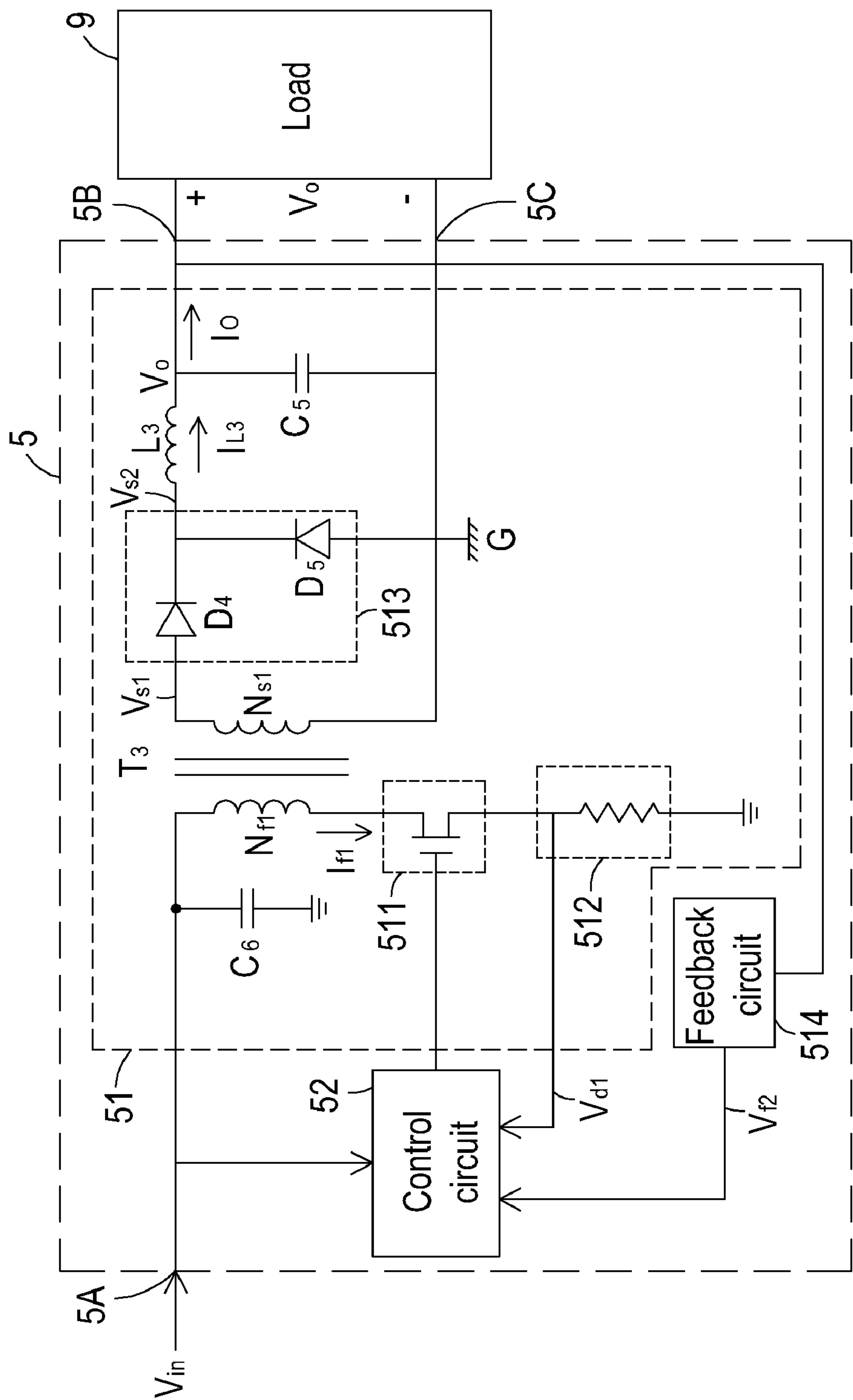


FIG. 8

1

SWITCHING POWER CONVERSION
CIRCUIT

FIELD OF THE INVENTION

The present invention relates to a power conversion circuit, and more particularly to a switching power conversion circuit.

BACKGROUND OF THE INVENTION

A switching power conversion circuit principally comprises a switching circuit and at least a magnetic element. The magnetic element is for example a transformer or an inductor. By alternately conducting or shutting off the switching circuit of the switching power conversion circuit, the input power is converted by the magnetic element into an output voltage including at least a regulated voltage level. The output voltage is used to drive the load that is connected to the output terminal of the switching power conversion circuit. In addition, the magnetic element can be used to achieve voltage-increasing, voltage-decreasing, filtering or other purposes.

When the switching circuit of the switching power conversion circuit is alternately conducted or shut off, the magnetic element will generate corresponding magnetic flux according to the formula $B = V \times T_{on} / (T_s \times A)$, in which B is the magnetic flux, V is the input voltage of the switching power conversion circuit, T_{on} is the on duration of the switching circuit, T_s is the coil turn of the magnetic element, and A is an effective area passing through the magnetic flux. Generally, the on duration T_{on} of the switching circuit is dependent on the output voltage to be transmitted to the load. As the output voltage is increased, the on duration T_{on} of the switching circuit is extended. Since the coil turn T_s and the effective area A are determined after the switching power conversion circuit is fabricated, the magnetic flux B is changed with the input voltage V and the on duration T_{on} of the switching circuit.

The switching circuit is usually operated at a constant switching frequency. As the output voltage is increased, the on duration T_{on} of the switching circuit is extended. The magnetic flux B generated may exceed the maximum saturation magnetic flux of the magnetic element. If the magnetic element is saturated, the impedance of the magnetic element becomes very small. Under this circumstance, the current flowing through the magnetic element becomes extremely large. Consequently, the magnetic element or other components of the switching power conversion circuit may be immediately burned out.

Moreover, the conventional switching power conversion circuit has a bootstrap circuit for driving the switching circuit at the high-voltage terminal of the switching power conversion circuit. Since the bootstrap circuit is very costly, the use of the bootstrap circuit increases extra cost. For solving these problems, some literatures have disclosed a method of adjusting the locations or the number of the switching circuit. Such a method, however, fails to precisely control the output current or the output voltage of the switching power conversion circuit, and thus the operation of the load is not optimized.

Therefore, there is a need of providing a switching power conversion circuit to obviate the drawbacks encountered from the prior art.

SUMMARY OF THE INVENTION

An object of the present invention provides a switching power conversion circuit for minimizing the possibility of

2

immediately burning out the magnetic element and other components of the switching power conversion circuit.

Another object of the present invention provides a switching power conversion circuit with no additional bootstrap circuit in order to reduce the fabricating cost.

A further object of the present invention provides a switching power conversion circuit for precisely controlling the load current, so that the operation of the load is optimized.

In accordance with an aspect of the present invention, there is provided a switching power conversion circuit for converting an input voltage into an output voltage and issuing the output voltage to a load. The switching power conversion circuit includes a power circuit, a feedback circuit and a control circuit. The power circuit is interconnected between an input terminal of the switching power conversion circuit and the load, and includes a switching circuit and a first magnetic element. The first magnetic element generates a magnetic flux change by alternately conducting or shutting off the switching circuit, so that the input voltage is converted into the output voltage by the power circuit. The feedback circuit has an input terminal connected to an output terminal of the power circuit. The feedback circuit generates a feedback signal according to the output voltage. The control circuit is connected to the input terminal of the switching power conversion circuit, the switching circuit and an output terminal of the feedback circuit for controlling an on duration and an off duration of the switching circuit, thereby maintaining the output voltage at a rated voltage. The off duration of the switching circuit is maintained at a constant interval under control of the control circuit. The on duration of the switching circuit is adjusted by the control circuit according to the feedback signal. The on duration of the switching circuit is adjusted to be a specified interval smaller than a maximum on duration according to the magnitude of the input voltage.

The above contents of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic circuit diagram of a switching power conversion circuit according to a first embodiment of the present invention;

FIG. 2 is a schematic circuit diagram illustrating a variation example of the switching power conversion circuit according to the first preferred embodiment of the present invention;

FIG. 3 is a schematic circuit diagram illustrating a switching power conversion circuit according to a second preferred embodiment of the present invention;

FIG. 4 is a timing waveform diagram schematically illustrating related current signals and the statuses of the switching circuit described in the switching power conversion circuit of FIG. 3;

FIG. 5 is a schematic circuit diagram illustrating a variation example of the switching power conversion circuit according to the second preferred embodiment of the present invention;

FIG. 6 is a schematic circuit diagram illustrating a switching power conversion circuit according to a third preferred embodiment of the present invention;

FIG. 7 is a timing waveform diagram schematically illustrating related current signals and the statuses of the switching circuit described in the switching power conversion circuit of FIG. 6; and

3

FIG. 8 is a schematic circuit diagram illustrating a variation example of the switching power conversion circuit according to the third preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this invention are presented herein for purpose of illustration and description only. It is not intended to be exhaustive or to be limited to the precise form disclosed.

FIG. 1 is a schematic circuit diagram of a switching power conversion circuit according to a first preferred embodiment of the present invention. In this embodiment, the switching power conversion circuit 1 is a fly-back switching power conversion circuit, but it is not limited thereto. After an input voltage V_{in} is received, the input voltage V_{in} is converted by the switching power conversion circuit 1 into an output voltage V_o required for powering a load 9.

As shown in FIG. 1, the switching power conversion circuit 1 principally comprises a power circuit 11, a control circuit 12 and a feedback circuit 113. The power circuit 11 is connected to the control circuit 12 and the load 9. The power circuit 11 comprises a first magnetic element, a switching circuit 111 and a rectifying and filtering circuit 112. In this embodiment, the first magnetic element is a transformer T. The primary winding assembly N_p of the transformer T is connected to the input terminal 1A of the switching power conversion circuit 1. The input voltage V_{in} is received by the primary winding assembly N_p and then magnetically transmitted to the secondary winding assembly N_s of the transformer T. As such, the secondary winding assembly N_s generates a conversion voltage V_s . The switching circuit 111 is connected to the control circuit 12, the primary winding assembly N_p and a common terminal. Under control of the control circuit 12, the switching circuit 111 is alternately conducted or shut off. As such, the electric energy received by the primary winding assembly N_p will be magnetically transmitted to the secondary winding assembly N_s of the transformer T.

When the switching circuit 111 is alternately conducted or shut off under control of the control circuit 12, the primary winding assembly N_p or the secondary winding assembly N_s of the transformer T will generate corresponding magnetic flux change according to the formula $B = V_{in} \times T_{on} / (T_s \times A)$, in which B is the magnetic flux generated on the primary winding assembly N_p or the secondary winding assembly N_s , V_{in} is the input voltage received at the input terminal 1A of the switching power conversion circuit 1, T_{on} is the on duration of the switching circuit 111, T_s is the coil turn of the primary winding assembly N_p or the secondary winding assembly N_s , and A is an effective area passing through the magnetic flux. Since the coil turn T_s of the primary winding assembly N_p or the secondary winding assembly N_s and the effective area A are determined after the switching power conversion circuit 1 is fabricated, the magnetic flux B is changed with the input voltage V_{in} and the on duration T_{on} of the switching circuit 111.

The rectifying and filtering circuit 112 is connected between the secondary winding assembly N_s and a first output terminal 1B and a second output terminal 1C of the switching power conversion circuit 1. The first output terminal 1B and the second output terminal 1C are connected to both ends of the load 9. The rectifying and filtering circuit 112 is used for rectifying and filtering the conversion voltage V_s , thereby generating the output voltage V_o . The rectifying and

4

filtering circuit 112 comprises a first diode D_1 and a first capacitor C_1 . The positive end of the first diode D_1 is connected to the secondary winding assembly N_s . The negative end of the first diode D_1 is connected to the first capacitor C_1 and an end of the load 9. The first capacitor C_1 is also connected to the other end of the load 9. In addition, the power circuit 11 further includes a second capacitor C_2 . The second capacitor C_2 is connected to the input terminal 1A of the switching power conversion circuit 1 and the primary winding assembly N_p . The second capacitor C_2 is used for filtering the input voltage V_{in} .

The input terminal of the feedback circuit 113 is connected to the output terminal of the rectifying and filtering circuit 112. The output terminal of the feedback circuit 113 is connected to the control circuit 12. According to the output voltage V_o , the feedback circuit 113 generates a feedback signal V_f to the control circuit 12.

The control circuit 12 is connected to the input terminal 1A of the switching power conversion circuit 1, the feedback circuit 113 and the switching circuit 111. The control circuit 12 is used for adjusting the on duration and the off duration of the switching circuit 111, so that the magnitude of the output voltage V_o is maintained at a rated voltage. In this embodiment, the off duration of the switching circuit 111 is maintained at a constant interval under control of the control circuit 12. According to the feedback signal V_f , the on duration of the switching circuit 111 is adjusted by the control circuit 12. According to the magnitude of the input voltage V_{in} , the on duration of the switching circuit 111 is adjusted to be a specified interval, which is smaller than a maximum on duration. Since the maximum on duration of the switching circuit 111 is varied with the magnitude of the input voltage V_{in} , the real on duration is correlated with the input voltage V_{in} according to a formula $T_{on} \leq K / V_{in}$, in which K is an adjustable parameter. Since the on duration T_{on} is restricted by the input voltage V_{in} , a ratio of the on duration T_{on} to the input voltage V_{in} is also restricted. As a consequence, the relation between the input voltage V_{in} and the on duration T_{on} of the switching circuit 111 may be changed by adjusting the adjustable parameter K under control of the control circuit 12.

In the above embodiment, when the switching circuit 111 is alternately conducted or shut off under control of the control circuit 12, the primary winding assembly N_p or the secondary winding assembly N_s of the transformer T will generate corresponding magnetic flux according to the formula $B = V_{in} \times T_{on} / (T_s \times A)$. Since the coil turn T_s of the primary winding assembly N_p or the secondary winding assembly N_s and the effective area A are determined after the switching power conversion circuit 1 is fabricated, the magnetic flux B is changed with the input voltage V_{in} and the on duration T_{on} of the switching circuit 111. According to the magnitude of the input voltage V_{in} , the on duration of the switching circuit 111 is adjusted to be a specified interval, which is smaller than a maximum on duration. The real on duration (i.e. the specified interval) is correlated with the input voltage V_{in} according to a formula $T_{on} < K / V_{in}$. In a case that T_{on} is replaced by K / V_{in} , the $B = V_{in} \times T_{on} / (T_s \times A)$ may be deduced as a new formula $B \leq K / (T_s \times A)$. Since the coil turn T_s and the effective area A are known value, the magnetic flux B is changed with the adjustable parameter K and restricted under an upper limit. In other words, by predetermining the adjustable parameter K under control of the control circuit 12, the magnetic flux B is restricted under the maximum saturation magnetic flux. Under this circumstance, when the switching circuit 111 is alternately conducted or shut off under control of the control circuit 12, the primary winding assembly N_p or the secondary winding assembly N_s of the transformer T fails to

5

be saturated. As a consequence, the possibility of immediately burning out the transformer T and other components of the switching power conversion circuit 1 will be largely reduced.

FIG. 2 is a schematic circuit diagram illustrating a variation example of the switching power conversion circuit according to the first preferred embodiment of the present invention. In this embodiment, the switching power conversion circuit 1 is a forward switching power conversion circuit, but it is not limited thereto. In comparison with the switching power conversion circuit 1 of FIG. 1, the rectifying and filtering circuit 112 further comprises a second magnetic element and a second diode D₂. An example of the second magnetic element is an inductor L. The inductor L is connected to the first diode D₁, the first capacitor C₁ and the load 9. The inductor L and the capacitor C₁ collectively forms a LC resonant circuit, thereby enhancing the filtering efficacy of the rectifying and filtering circuit 112. The negative end of the second diode D₂ is connected to the first diode D₁ and the inductor L. The positive end of the second diode D₂ is connected to the first capacitor C₁.

In the above embodiment, when the switching circuit 111 is alternately conducted or shut off under control of the control circuit 12, the inductor L will also generate a magnetic flux change according to the similar formula relating to primary winding assembly N_p or the secondary winding assembly N_s of the transformer T. In other words, the magnetic flux of the inductor L is changed with the input voltage V_{in} and the on duration T_{on} of the switching circuit 111. According to the magnitude of the input voltage V_{in}, the on duration of the switching circuit 111 is adjusted to be a specified interval, which is smaller than a maximum on duration. The real on duration (i.e. the specified interval) is correlated with the input voltage V_{in} according to a formula $T_{on} \leq K/V_{in}$. In other words, by predetermining the adjustable parameter K under control of the control circuit 12, the magnetic flux of the inductor L is restricted under the maximum saturation magnetic flux. As a consequence, the possibility of immediately burning out the inductor L of the switching power conversion circuit 1 will be largely reduced.

FIG. 3 is a schematic circuit diagram illustrating a switching power conversion circuit according to a second preferred embodiment of the present invention. In this embodiment, the switching power conversion circuit 1 is a buck switching power conversion circuit, but it is not limited thereto. After an input voltage V_{in} is received, the input voltage V_{in} is converted by the switching power conversion circuit 3 into an output voltage V_o required for powering a load 9.

As shown in FIG. 3, the switching power conversion circuit 3 principally comprises a power circuit 31, a control circuit 32 and a feedback circuit 313. The power circuit 31 is connected to the control circuit 32 and the load 9. The power circuit 31 comprises a first magnetic element, a first capacitor C₃, a switching circuit 311 and a detecting circuit 312. In this embodiment, the first magnetic element is an inductor L₂. A first end of the inductor L₂ is connected to the input terminal 3A of the switching power conversion circuit 3. After the input voltage V_{in} is received by the inductor L₂, an inductor current I_L is generated. A second end of the inductor L₂ is connected to the first capacitor C₃ and the load 9 such that the inductor current I_L may flow to the first capacitor C₃ and the load 9. An end of the first capacitor C₃ is connected to the inductor L₂ and the load 9. The other end of the first capacitor C₃ is connected to the switching circuit 311.

The switching circuit 311 is connected to the load 9, the first capacitor C₃, the control circuit 32 and the detecting circuit 312. Under control of the control circuit 32, the switch-

6

ing circuit 311 is alternately conducted or shut off. As such, the inductor L₂ and the first capacitor C₃ will be charged by the input voltage V_{in} when the switching circuit 311 is conducted; and the inductor L₂ discharges the stored energy when the switching circuit 311 is shut off. In other words, by alternately conducting or shut off the switching circuit 311, a magnetic flux change is generated on the inductor L₂. At the same time, the output voltage V_o, which is equal to the voltage difference across the first output terminal 3B and a second output terminal 3C of the switching power conversion circuit 3, and the load current I_o are transmitted to the load 9.

The detecting circuit 312 is interconnected between the switching circuit 311 and a common terminal. When the switching circuit 311 is conducted, the detecting circuit 312 receives the inductor current I_L, thereby generating a detecting voltage V_d. In this embodiment, the detecting circuit 312 includes a resistor.

The power circuit 31 further comprises a second capacitor C₄ and a first diode D₃. An end of the second capacitor C₄ is connected to the input terminal 3A of the switching power conversion circuit 3 and the inductor L₂. The other end of the second capacitor C₄ is connected to the common terminal. The second capacitor C₂ is used for filtering the input voltage V_{in}. The negative end of the first diode D₃ is connected to the second capacitor C₄ and the inductor L₂. The positive end of the first diode D₃ is connected to the first capacitor C₃. When the switching circuit 311 is shut off, the first diode D₃ provides a discharging path of the inductor L₂.

The input terminal of the feedback circuit 313 is connected to the output terminals of the power circuit 31. The output terminal of the feedback circuit 313 is connected to the control circuit 32. According to the output voltage V_o, the feedback circuit 313 generates a feedback signal V_f to the control circuit 32.

The input terminal of the control circuit 32 is connected to the detecting circuit 312 and the feedback circuit 313 for receiving the detecting voltage V_d from the detecting circuit 312 and the feedback signal V_f from the feedback circuit 313. The output terminal of the control circuit 32 is connected to a control terminal of the switching circuit 311. The control circuit 32 is used for adjusting the on duration and the off duration of the switching circuit 311, so that the magnitude of the output voltage V_o is maintained at a rated voltage. In this embodiment, the off duration of the switching circuit 311 is maintained at a constant interval under control of the control circuit 32. According to the feedback signal V_f, the on duration of the switching circuit 311 is adjusted by the control circuit 32. An upper limit current value I_m (as shown in FIG. 4) has been predetermined by the control circuit 32. According to the detecting voltage V_d from the detecting circuit 312, the control circuit 32 will control the switching circuit 311 to be shut off if the inductor current I_L reaches the current upper limit value I_m.

FIG. 4 is a timing waveform diagram schematically illustrating related current signals and the statuses of the switching circuit 311 described in the switching power conversion circuit of FIG. 3. At the time spot t₁, the switching circuit 311 is conducted under control of the control circuit 32, so that the electric energy of the input voltage V_{in} is stored into the inductor L₂ and the first capacitor C₃ (in a charge state). The inductor current I_L of the inductor L₂ is gradually increased and divided to flow to the first capacitor C₃ and the load 9. Since the switching circuit 311 is conducted, the inductor current I_L may flow to the detecting circuit 312 through the switching circuit 311. According to the magnitude of the inductor current I_L, the detecting circuit 312 generates the detecting voltage V_d to the control circuit 32.

7

At the time spot t_2 , the inductor current I_L is gradually increased to the upper limit current value I_m . Meanwhile, according to the detecting voltage V_d , the control circuit **32** realizes that the inductor current I_L reaches the upper limit current value I_m . Accordingly, the switching circuit **311** is shut off under control of the control circuit **32**. At the moment when the switching circuit **311** is shut off, the peak value I_p of the inductor current I_L is equal to the upper limit current value I_m . Meanwhile, the electric energy stored in the inductor L_2 begins to discharge through the first diode D_3 and thus the inductor current I_L is gradually decreased. Since the off duration of the switching circuit **311** is maintained at a constant interval (e.g. T_f) under control of the control circuit **32**, the switching circuit **311** is conducted under control of the control circuit **32** at the time spot t_3 , in which $t_3 = t_2 + T_f$. At the moment when the switching circuit **311** is conducted, the inductor current I_L reaches a trough current value I_a . Meanwhile, the electric energy of the input voltage V_{in} is stored into the inductor L_2 and the first capacitor C_3 (in the charge state). The inductor current I_L of the inductor L_2 is gradually increased. The above procedures are repeated, so that the input voltage V_{in} is converted by the switching power conversion circuit **3** into the output voltage V_o required for powering the load **9**.

Please refer to FIG. 3 and FIG. 4. When the switching power conversion circuit **3** provides the output voltage V_o to the load **9**, the load current I_o on the load **9** is changed with the peak value I_p and the trough current value I_a of the inductor current I_L according to the formula $I_o = I_a + (I_p - I_a)/2$. In addition, the relation between the peak value I_p and the trough current value I_a may be indicated as $I_a = I_p - (V_o \times T_{off})/L_f$ in which V_o is the output voltage of the switching power conversion circuit **3**, T_{off} is the off duration of the switching circuit **311**, and L_f is the inductance of the inductor L_2 . As a consequence, the trough current value I_a is changed with the peak value I_p , the output voltage V_o , the off duration T_{off} and the inductance L_f of the inductor. Since the inductance L_f is determined after the inductor L_2 is fabricated, the off duration T_{off} of the switching circuit **311** is a constant interval T_f and the peak value I_p of the inductor current I_L is equal to the upper limit current value I_m , the trough current value I_a is only changed with the output voltage V_o . Due to the capacitance property of the first capacitor C_3 , the variation of the output voltage V_o is very tiny and thus the variation of the trough current value I_a is very tiny.

Since the load current I_o on the load **9** is changed with the peak value I_p and the trough current value I_a of the inductor current I_L and the variation of the trough current value I_a is very tiny, the load current I_o is mainly dependent on the peak value I_p . Since the peak value I_p of the inductor current I_L is equal to the upper limit current value I_m , the peak value I_p of the inductor current I_L may be controlled by adjusting the upper limit current value I_m under control of the control circuit **32**. Under this circumstance, the load current I_o can be precisely maintained at a constant value, so that the operation of the load **9** is optimized.

Please refer to FIG. 3 again. Since the switching circuit **311** is located at the low-voltage terminal, no additional bootstrap circuit is required to drive the switching circuit **311** and the switching power conversion circuit **3** is relatively cost-effective. Moreover, since the load current I_o is precisely maintained at a constant value, the operation of the load **9** is optimized.

FIG. 5 is a schematic circuit diagram illustrating a variation example of the switching power conversion circuit according to the second preferred embodiment of the present invention. In comparison with the switching power conversion circuit **3**

8

of FIG. 3, the control circuit **32** is connected to the switching circuit **311**, the detecting circuit **312**, the feedback circuit **313** and also connected to the input terminal **3A** of the switching power conversion circuit **3**. Similarly, according to the magnitude of the input voltage V_{in} , the on duration of the switching circuit **311** is adjusted to be a specified interval, which is smaller than a maximum on duration under control of the control circuit **32**. In this embodiment, the load current I_o can be precisely maintained at a constant value, so that the operation of the load **9** is optimized. In addition, when the switching circuit **311** is alternately conducted or shut off, the magnetic flux of the inductor L_2 is restricted under the maximum saturation magnetic flux by predetermining the adjustable parameter K under control of the control circuit **32**. For example, the magnetic flux of the inductor L_2 is restricted under the maximum saturation magnetic flux. As a consequence, the possibility of immediately burning out the inductor L_2 or other components of the switching power conversion circuit **3** will be largely reduced.

FIG. 6 is a schematic circuit diagram illustrating a switching power conversion circuit according to a third preferred embodiment of the present invention. In this embodiment, the switching power conversion circuit **5** is an isolation switching power conversion circuit. After an input voltage V_{in} is received, the input voltage V_{in} is converted by the switching power conversion circuit **5** into an output voltage V_o required for powering a load **9**.

As shown in FIG. 6, the switching power conversion circuit **5** principally comprises a power circuit **51**, a control circuit **52** and a feedback circuit **514**. The power circuit **51** is connected to the control circuit **52** and the load **9**. The power circuit **51** comprises a first magnetic element, a first capacitor C_5 , a switching circuit **511**, a detecting circuit **512**, a rectifying circuit **513** and a second magnetic element. In this embodiment, the second magnetic element is an isolation transformer T_3 . The primary winding assembly N_{f1} of the transformer T_3 is connected to the input terminal **5A** of the switching power conversion circuit **5**. The input voltage V_{in} is received by the primary winding assembly N_{f1} and then magnetically transmitted to the secondary winding assembly N_{s1} of the transformer T_3 . As such, the secondary winding assembly N_{s1} generates a conversion voltage V_{s1} . In addition, when the input voltage V_{in} is received by the primary winding assembly N_{f1} , a primary current I_{f1} is generated.

The rectifying circuit **513** is connected to the secondary winding assembly N_{s1} of the transformer T_3 for rectifying the conversion voltage V_{s1} into a rectified voltage V_{s2} . In this embodiment, the rectifying circuit **513** comprises a first diode D_4 and a second diode D_5 . The positive end and the negative end of the first diode D_4 are respectively connected to the secondary winding assembly N_{s1} of the isolation transformer T_3 and the negative end of the second diode D_5 . The positive end of the second diode D_5 is connected to an insulation common terminal G .

In this embodiment, the first magnetic element is an inductor L_3 . A first end of the inductor L_3 is connected to the rectifying circuit **513**. After the rectified voltage V_{s2} transmitted from the rectifying circuit **513** is received by the inductor L_3 , an inductor current I_{L3} is generated. A second end of the inductor L_3 is connected to the first capacitor C_5 and the load **9** such that the inductor current I_{L3} may flow to the first capacitor C_5 and the load **9**. Due to the inherent property of the isolation transformer T_3 , the inductor current I_{L3} and the primary current I_{f1} are in a proportional relation. The proportional relation is equal to the turn ratio of the primary winding assembly N_{f1} to the secondary winding assembly N_{s1} . Assuming the coil turn of the primary winding assembly N_{f1} is

9

double of the coil turn of the secondary winding assembly N_{s1} , the ratio of the inductor current I_{L3} to the primary current I_{p1} is 2:1. An end of the first capacitor C_5 is connected to the inductor L_3 and the load **9**. The other end of the first capacitor C_5 is connected to the insulation common terminal G for filtering purpose.

The switching circuit **511** is connected to the control circuit **52**, the primary winding assembly N_{p1} of the transformer T_3 and the detecting circuit **512**. Under control of the control circuit **52**, the switching circuit **511** is alternately conducted or shut off. As such, the electric energy received by the primary winding assembly N_{p1} of the transformer T_3 will be magnetically transmitted to the secondary winding assembly N_{s1} . When the switching circuit **511** is conducted, the inductor L_3 and the first capacitor C_5 will be charged by the rectified voltage V_{s2} and thus the inductor current I_{L3} is generated. When the switching circuit **511** is shut off, the inductor L_3 discharges the stored energy. In other words, by alternately conducting or shut off the switching circuit **511**, a magnetic flux change is generated on the inductor L_3 . At the same time, the output voltage V_o , which is equal to the voltage difference across the first output terminal **5B** and a second output terminal **5C** of the switching power conversion circuit **5**, and the load current I_o are transmitted to the load **9**.

The detecting circuit **512** is interconnected between the switching circuit **511** and a common terminal. When the switching circuit **511** is conducted, the detecting circuit **512** receives the primary current I_{p1} , thereby generating a detecting voltage V_{d1} . Due to the inherent property of the isolation transformer T_3 , the inductor current I_{L3} and the primary current I_{p1} are in a proportional relation. In this embodiment, the ratio of the inductor current I_{L3} to the primary current I_{p1} is 2:1. The detecting circuit **512** is composed of a resistor.

The input terminal of the feedback circuit **514** is connected to the output terminals of the power circuit **51**. The output terminal of the feedback circuit **514** is connected to the control circuit **52**. According to the output voltage V_o , the feedback circuit **514** generates a feedback signal V_{f2} to the control circuit **52**.

The power circuit **51** further comprises a second capacitor C_6 . An end of the second capacitor C_6 is connected to the input terminal **5A** of the switching power conversion circuit **5** and the primary winding assembly N_{p1} of the transformer T_3 . The other end of the second capacitor C_6 is connected to the common terminal. The second capacitor C_6 is used for filtering the input voltage V_{in} .

The input terminal of the control circuit **52** is connected to the detecting circuit **512** and the feedback circuit **514** for receiving the detecting voltage V_{d1} from the detecting circuit **512** and the feedback signal V_{f2} from the feedback circuit **514**. The output terminal of the control circuit **52** is connected to a control terminal of the switching circuit **511**. The control circuit **52** is used for adjusting the on duration and the off duration of the switching circuit **511**, so that the magnitude of the output voltage V_o is maintained at a rated voltage. In this embodiment, the off duration of the switching circuit **511** is maintained at a constant interval under control of the control circuit **52**. An upper limit current value I_{m1} (as shown in FIG. 7) has been predetermined by the control circuit **52**. According to the detecting voltage V_{d1} from the detecting circuit **512**, the control circuit **52** will control the switching circuit **511** to be shut off if the inductor current I_{L3} reaches the current upper limit I_{m1} .

FIG. 7 is a timing waveform diagram schematically illustrating related current signals and the statuses of the switching circuit **511** described in the switching power conversion circuit of FIG. 6. At the time spot t_1 , the switching circuit **511**

10

is conducted under control of the control circuit **52**, so that the primary current I_{p1} is gradually increased and flows to the detecting circuit **512** through the switching circuit **511**. At the same time, the secondary winding assembly N_{s1} generates a conversion voltage V_{s1} . By the rectifying circuit **513**, the conversion voltage V_{s1} is rectified into a rectified voltage V_{s2} , which will charge the inductor L_3 and the first capacitor C_5 . During the charging period, the inductor current I_{L3} is gradually increased. Assuming the coil turn of the primary winding assembly N_{p1} is double of the coil turn of the secondary winding assembly N_{s1} , the ratio of the inductor current I_{L3} to the primary current I_{p1} is 2:1.

At the time spot t_2 , the inductor current I_{L3} is gradually increased to the upper limit current value I_{m1} . Meanwhile, according to the detecting voltage V_{d1} , the control circuit **52** realizes that the inductor current I_{L3} reaches the upper limit current value I_{m1} . Accordingly, the switching circuit **511** is shut off under control of the control circuit **52**. At the moment when the switching circuit **511** is shut off, the peak value I_{p1} of the inductor current I_{L3} is equal to the upper limit current value I_{m1} .

When switching circuit **511** is shut off at the time spot t_2 , the electric energy stored in the inductor L_3 begins to discharge and thus the inductor current I_{L3} is gradually decreased. Since the off duration of the switching circuit **511** is maintained at a constant interval (e.g. T_{f1}) under control of the control circuit **52**, the switching circuit **511** is conducted under control of the control circuit **52** at the time spot t_3 , in which $t_3 = t_2 + T_{f1}$. At the moment when the switching circuit **511** is conducted, the inductor current I_{L3} reaches a trough current value I_{a1} . Meanwhile, the electric energy of the rectified voltage V_{s2} is stored into the inductor L_3 (in the charge state) and thus the inductor current I_{L3} of the inductor L_3 is gradually increased.

Please refer to FIG. 6 and FIG. 7 again. When the switching power conversion circuit **5** provides the output voltage V_o to the load **9**, the load current I_o on the load **9** is changed with the peak value I_{p1} and the trough current value I_{a1} of the inductor current I_{L3} according to the formula $I_o = I_{a1} + (I_{p1} - I_{a1})/2$. In addition, the relation between the peak value I_{p1} and the trough current value I_{a1} may be indicated as $I_a = I_{p1} - (V_o \times T_{off})/L_f$ in which V_o is the output voltage of the switching power conversion circuit **5**, T_{off} is the off duration of the switching circuit **511**, and L_f is the inductance of the inductor L_3 . As a consequence, the trough current value I_{a1} is changed with the peak value I_{p1} , the output voltage V_o , the off duration T_{off} and the inductance L_f of the inductor. Since the inductance L_f is determined after the inductor L_3 is fabricated, the off duration T_{off} of the switching circuit **511** is a const interval T_{f1} and the peak value I_{p1} of the inductor current I_{L3} is equal to the upper limit current value I_{m1} , the trough current value I_{a1} is only changed with the output voltage V_o . Due to the capacitance property of the first capacitor C_5 , the variation of the output voltage V_o is very tiny and thus the variation of the trough current value I_{a1} is very tiny.

Since the load current I_o on the load **9** is changed with the peak value I_{p1} and the trough current value I_{a1} of the inductor current I_{L3} and the variation of the trough current value I_{a1} is very tiny, the load current I_o is mainly dependent on the peak value I_{p1} . Since the peak value I_{p1} of the inductor current I_{L3} is equal to the upper limit current value I_{m1} , the peak value I_{p1} of the inductor current I_{L3} may be controlled by adjusting the upper limit current value I_{m1} under control of the control circuit **52**. Under this circumstance, the load current I_o can be precisely maintained at a constant value, so that the operation of the load **9** is optimized.

11

FIG. 8 is a schematic circuit diagram illustrating a variation example of the switching power conversion circuit according to the third preferred embodiment of the present invention. In comparison with the switching power conversion circuit 5 of FIG. 6, the control circuit 52 is connected to the switching circuit 511, the detecting circuit 512, the feedback circuit 514 and also connected to the input terminal 5A of the switching power conversion circuit 5. Similarly, according to the magnitude of the input voltage V_{in} , the on duration of the switching circuit 511 is adjusted to be a specified interval, which is smaller than a maximum on duration under control of the control circuit 52. In this embodiment, the load current I_o can be precisely maintained at a constant value, so that the operation of the load 9 is optimized. In addition, when the switching circuit 511 is alternately conducted or shut off, the magnetic fluxes of the first and second magnetic elements are restricted under the maximum saturation magnetic flux. As a consequence, the possibility of immediately burning out the components of the switching power conversion circuit 5 will be largely reduced.

From the above description, the on duration of the switching circuit is adjusted to be a specified interval smaller than a maximum on duration under control of the control circuit according to the magnitude of the input voltage. When the switching circuit is alternately conducted or shut off, the magnetic fluxes of the magnetic element is restricted under the maximum saturation magnetic flux. As a consequence, the possibility of immediately burning out the components of the switching power conversion circuit will be largely reduced.

Moreover, since the switching circuit is located at the low-voltage terminal, no additional bootstrap circuit is required to drive the switching circuit and the switching power conversion circuit is relatively cost-effective. Moreover, since the load current is precisely maintained at a constant value, the operation of the load is optimized.

While the invention has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention needs not be limited to the disclosed embodiment. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

What is claimed is:

1. A switching power conversion circuit for converting an input voltage into an output voltage and issuing said output voltage to a load, said switching power conversion circuit comprising:

a power circuit interconnected between an input terminal of said switching power conversion circuit and said load, and comprising a switching circuit and a first magnetic element, wherein said first magnetic element generates a magnetic flux change by alternately conducting or shutting off said switching circuit, so that said input voltage is converted into said output voltage by said power circuit;

a feedback circuit having an input terminal connected to an output terminal of said power circuit, wherein said feedback circuit generates a feedback signal according to said output voltage; and

a control circuit connected to said input terminal of said switching power conversion circuit, said switching circuit and an output terminal of said feedback circuit for controlling an on duration and an off duration of said switching circuit, thereby maintaining said output voltage at a rated voltage, wherein said off duration of said

12

switching circuit is maintained at a constant interval under control of said control circuit, said on duration of said switching circuit is adjusted by said control circuit according to said feedback signal, and said on duration of said switching circuit is adjusted to be a specified interval smaller than a maximum on duration according to the magnitude of said input voltage.

2. The switching power conversion circuit according to claim 1 wherein said first magnetic element is connected to said input terminal of said switching power conversion circuit for converting said input voltage into a conversion voltage.

3. The switching power conversion circuit according to claim 2 wherein said first magnetic element is a transformer, and said switching circuit is interconnected between said transformer and a common terminal.

4. The switching power conversion circuit according to claim 2 further comprising a rectifying and filtering circuit, which is interconnected between said first magnetic element and said load for rectifying and filtering said conversion voltage and generating said output voltage, and said rectifying and filtering circuit includes a first diode and a first capacitor, wherein the positive end of said first diode is connected to said first magnetic element, the negative end of said first diode is connected to an end of said first capacitor and said load, and the other end of said first capacitor is connected to a common terminal.

5. The switching power conversion circuit according to claim 1 wherein said first magnetic element is connected to said input terminal of said switching power conversion circuit, and said first magnetic element generates a load current to said load by alternately conducting or shutting off said switching circuit.

6. The switching power conversion circuit according to claim 5 wherein said first magnetic element is an inductor.

7. The switching power conversion circuit according to claim 5 further comprising a first capacitor and a detecting circuit, wherein an end of said first capacitor is connected to said first magnetic element and said load, and the other end of said first capacitor is connected to said switching circuit, an end of said detecting circuit is connected to said control circuit and said switching circuit, the other end of said detecting circuit is connected to a common terminal, and said detecting circuit receives a current generated by said first magnetic element when the switching circuit is conducted, thereby generating a detecting voltage.

8. The switching power conversion circuit according to claim 7 wherein an upper limit current value is predetermined by said control circuit, wherein if said current generated by said first magnetic element reaches said current upper limit value, said switching circuit is shut off under control of said control circuit according to said detecting voltage, so that said load current is kept constant.

9. The switching power conversion circuit according to claim 7 further comprising a first diode, wherein the negative end of said first diode is connected to said first magnetic element, and the positive end of said first diode is connected to said first capacitor, thereby providing a discharging path of said first magnetic element.

10. The switching power conversion circuit according to claim 1 further comprising a second magnetic element, which is connected to said input terminal of said switching power conversion circuit for converting said input voltage into a conversion voltage.

11. The switching power conversion circuit according to claim 10 wherein said second magnetic element is an isolation transformer having a primary winding assembly and a secondary winding assembly.

13

12. The switching power conversion circuit according to claim 11 further comprising a rectifying circuit, which is connected to said second magnetic element for rectifying said conversion voltage into a rectified voltage, wherein said rectifying circuit comprises a first diode and a second diode, the positive end and the negative end of said first diode are respectively connected to said second magnetic element and said first magnetic element, and the positive end and the negative end of said second diode are respectively connected to said first magnetic element and an insulation common terminal.

13. The switching power conversion circuit according to claim 11 wherein said first magnetic element is an inductor interconnected between said rectifying circuit and said load, wherein when said switching circuit is conducted, said inductor is charged by said rectified voltage and generates a current, and when said switching circuit is shut off, said inductor discharges such that said output voltage and a load current is transmitted to said load.

14. The switching power conversion circuit according to claim 12 further comprising a first capacitor, wherein an end of said first capacitor is connected to said first magnetic element and said load, and the other end of said first capacitor is connected to an insulation common terminal.

15. The switching power conversion circuit according to claim 12 wherein said switching circuit is connected to said second magnetic element.

16. The switching power conversion circuit according to claim 15 further comprising a detecting circuit, wherein an end of said detecting circuit is connected to said control circuit and said switching circuit, the other end of said detecting circuit is connected to a common terminal, and when said switching circuit is conducted, said detecting circuit receives

14

a primary current generated by said primary winding assembly of said second magnetic element and senses said current generated by said first magnetic element, thereby generating a detecting voltage according to said current generated by said first magnetic element, wherein said primary current and said current generated by said first magnetic element are in a proportional relation.

17. The switching power conversion circuit according to claim 16 wherein an upper limit current value is predetermined by said control circuit, wherein if said current generated by said first magnetic element reaches said current upper limit value, said switching circuit is shut off under control of said control circuit according to said detecting voltage, so that said load current is kept constant.

18. The switching power conversion circuit according to claim 16 wherein said proportional relation is equal to the turn ratio of said primary winding assembly to said secondary winding assembly.

19. The switching power conversion circuit according to claim 1 wherein said maximum on duration is varied according to the magnitude of said input voltage, and the relation between said input voltage and said on duration of said switching circuit is changed by adjusting an adjustable parameter under control of said control circuit.

20. The switching power conversion circuit according to claim 1 further comprising a second capacitor, wherein an end of said second capacitor is connected to said input terminal of said switching power conversion circuit, and the other end of said second capacitor is connected to a common terminal for filtering said input voltage.

* * * * *