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(54) Switching mode power supply with a multi-mode controller

Schaltnetzteil mit Mehrmodus-Steuerung

Alimentation électrique de mode de commutation doté d’un contrôleur multimodal

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(73) Proprietor: **Monolithic Power Systems, Inc.**
San Jose, CA 95119 (US)

(72) Inventors:
- **Li, En**
  Hangzhou 310012 (CN)
- **Zhang, Junming**
  Hangzhou 310012 (CN)
- **Ren, Yuancheng**
  Hangzhou 310012 (CN)

(74) Representative: **Leach, James et al**
Mewburn Ellis LLP
City Tower
40 Basinghall Street
London EC2V 5DE (GB)

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Description

FIELD

[0001] The technology described in this patent document relates generally to switching mode power supplies.

[0002] In a typical switching mode power supply, the switching frequency is either fixed or increases as the load becomes lighter, often resulting in poor efficiency at light loads and poor average efficiency. Switching mode power supplies also typically include current controllers that limit the peak current to a fixed value, often causing acoustic noise at light loads.

[0003] U.S. patent number 5,991,172 discloses single-stage single-switch flyback converter with input current shaping and output voltage regulation comprising current limit control based on a secondary side feedback signal, and frequency control.

[0004] US patent application publication number 2005/0046399 discloses a power supply having a normal operation mode and a standby operation mode.

[0005] U.S. patent number 7,433,211 discloses a system and method for input current shaping in a power converter.

[0006] US patent number 5,390,101 discloses a flyback power supply having a VCO controlled switching rate.

[0007] The present invention provides a multi-mode controller as set out in claim 1, a switching mode power supply as set out in claim 14 and a method for controlling a switching mode power supply as set out in claim 15.

[0008] In accordance with the teachings described herein, a switching mode power supply with a multi-mode controller may be provided. The switching mode power supply may include a transformer having a primary winding and a secondary winding to supply power to a load. A feedback circuit may be included to generate a feedback signal that varies in relation to the load on the secondary winding. The multi-mode controller may include a switching circuit, a frequency control circuit and a current limiting circuit. The switching circuit may be coupled to the primary winding to control current flow through the primary winding. The frequency control circuit may control a switching frequency of the switching circuit based on the feedback signal. The current limiting circuit may limit current flow through the primary winding by causing the switching circuit to suspend current flow through the primary winding when the current reaches a peak current limit that is set based on the feedback signal.

[0009] A method for controlling a switching mode power supply may include the following steps: regulating an output voltage of the switching mode power supply by switching a transformer on and off at a switching frequency; generating a feedback signal that varies in relation to a load coupled to the output voltage; controlling the switching frequency based on the feedback signal; and limiting a peak current through a primary winding of the transformer based on the feedback signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

Fig. 1 is a diagram of an example switching mode power supply having a multi-mode controller.

Fig. 2 is a diagram of an example multi-mode controller for a switching mode power supply.

Fig. 3 is a graph illustrating an example four-mode operation of the multi-mode controller of Fig. 2.

Fig. 4 is a graph illustrating an example three-mode operation of the multi-mode controller of Fig. 2.

Fig. 5 is a diagram of another example multi-mode controller for a switching mode power supply.

Fig. 6 is a graph illustrating an example four-mode operation of the multi-mode controller of Fig. 5.

Fig. 7 is a graph illustrating an example three-mode operation of the multi-mode controller of Fig. 5.

DETAILED DESCRIPTION

[0011] Fig. 1 is a diagram of an example switching mode power supply 100 having a multi-mode controller 102. The switching mode power supply 100 includes a rectifier bridge 104, a transformer 106, a feedback circuit 108, and the multi-mode controller 102. The transformer 106, in this example, includes a primary winding 110, a main secondary winding 112, and an auxiliary secondary winding 114. In operation, the rectifier bridge 104 receives an AC input voltage (VAC) that it converts into a DC input voltage received by the primary winding 110 of the transformer 106. The transformer 106 is controlled by the multi-mode controller 102 to generate DC output voltages on the secondary windings 112, 114 of the transformer 106. The multi-mode controller 102 controls the current flow through the primary winding 110 of the transformer to effectively switch the transformer 106 on and off. The main secondary winding 112 supplies an output voltage (V_{OUT}) to the load 110 and the auxiliary secondary winding 114 provides a DC voltage source (V_{CC}) to the multi-mode controller 102. Also illustrated in Fig. 1 is an input capacitor (C_{IN}) that stores and filters the DC input voltage, an LC circuit (L_1, C_1, C_2) that stores and filters the DC output voltage (V_{OUT}), diode circuits that prevent current flow back into the secondary windings 112, 114, and a RCD snubber circuit connected across the primary winding 110.

[0012] The feedback circuit 108 generates a feedback signal (FB) that is inversely proportional to the load 110 on the main secondary winding 112 of the transformer 106. As described in more detail below, the feedback signal (FB) is used by the multi-mode controller 102 to control the switching frequency and the peak current of the transformer 106 as a function of the load. In addition, the feedback circuit 108 provides a voltage regulator that may be used to adjust the DC output voltage (V_{OUT}) to a desired level. More specifically, the feedback circuit 108 includes a shunt regulator 118 and an optocoupler

120, 122. The desired DC voltage output (V_{OUT}) may be set by varying the resistor values in the shunt regulator 118. The optocoupler includes a photodiode 120 and a phototransistor 122. In operation, the intensity of the light emitted by the photodiode 120 is inversely proportional to the load 116. As the intensity of the photodiode 120 increases, so does the conduction of the phototransistor 122, which generates the feedback signal (FB). Therefore, feedback signal (FB) is inversely proportional to the load 116, *i.e.,* it increases as the load 116 becomes lighter and decreases as the load 116 becomes heavier. It should be understood, however, that in other examples the feedback circuit 108 and multi-mode controller 102 may be configured such that the feedback signal (FB) is proportional to the load or otherwise varies in relation to the load.

[0013] The multi-mode controller 102 includes a switching circuit that controls current flow through the primary winding 110 of the transformer 106. The power supplied to the load 116 may thus be controlled by varying the frequency at which the switching circuit switches the current through the primary winding 110 on and off. This is commonly referred to as the switching frequency of the transformer. The multi-mode controller 102 further includes a frequency control circuit that controls the switching frequency as a function of the feedback signal (FB), which is inversely proportional to the load 116 on the transformer's main secondary winding 112. In addition, the multi-mode controller 102 includes a current limiting circuit that sets a maximum peak current by causing the switching circuit to suspend current flow through the primary winding 110 when the current reaches a peak current limit that is controlled as a function of the feedback signal (FB). In this way, both the switching frequency and the maximum peak current may be regulated based on the load 116 in order to improve system performance. For instance, the multi-mode controller 102 may be configured to cause the switching frequency to decrease as the load 116 becomes lighter to provide high efficiency at lighter loads and a high average efficiency. The multi-mode controller 102 may be further configured to set the peak current limit proportionally to the load 116 to prevent mechanical resonance of the transformer 106 at lighter loads.

[0014] Fig. 2 depicts an example multi-mode controller 200, which may be used in the switching mode power supply 100 of Fig. 1. The multi-mode controller 200 includes a switching circuit 202, a frequency control circuit 204, a current limiting circuit 206 and a burst mode control circuit 208, 210, 228. The switching circuit 202 includes a MOSFET switch 211, an RS flip-flop 212, a logic gate 215 and a driver 217. The frequency control circuit 204 includes a current source 213, an electronic switch 214 *(e.g.,* a MOSFET switch), a comparator 216, a Zener diode 218, a voltage divider 220 and a delay circuit 221. The frequency control circuit 204 also includes an external capacitor (Ct) shown in Fig. 1. The current limiting circuit 206 includes a leading edge blanking (LEB) circuit 222, a comparator 224, a voltage reference (V_{SENSE}) 226 and a voltage subtracter 228. The current limiting circuit 206 further includes an external resistor (R_{SENSE}) shown in Fig. 1. The burst mode control circuit includes a Schmitt trigger comparator 208, a voltage reference 210 and a voltage subtracter 228.

[0015] In operation, the frequency control circuit 204 provides a voltage-controlled oscillator that controls the switching frequency of the MOSFET 211 based on the voltage at node 230. Specifically, when the Q output of the RS flip-flop 212 is in a logic low state, both the MOSFET switch 211 and the electronic switch 214 are open. This causes the current source 213 to charge the external capacitor (Ct), thereby increasing the voltage at the positive terminal of the comparator 216. When this voltage reaches the threshold voltage at node 230, a logic high signal is output from the comparator 216 to the S input of the flip-flop 212, causing the Q output to transition to a logic high state. When the Q output of the RS flip-flop 212 transitions to a logic high state, the MOSFET switch 211 closes for a preset time (T_{PULSE}), causing the external capacitor (Ct) to discharge to zero. Thus, the switching frequency of the MOSFET switch 211 may be controlled by varying the voltage at node 230. Depending on the operating mode of the controller 200, as described below with reference to Figs. 3 and 4, the voltage at node 230 may be determined by either the feedback signal (FB) or the breakdown voltage (V_{ZENER}) of the Zener diode 218.

[0016] The current limiting circuit 206 controls the peak current through the primary winding by comparing the voltage at the source terminal of the multi-mode controller 200 (*i.e.,* the voltage across the external R_{SENSE} resistor) with a threshold voltage at node 240. The LEB circuit 222 is a known circuit that reduces spikes in the signal by introducing a short delay. When the voltage at the positive terminal of the comparator 224 reaches the threshold voltage at node 240, a logic high signal is output from the comparator 224 to the R input of the flip-flop 212, causing the MOSFET switch 211 to open and suspend current flow through the primary winding. Depending on the operating mode of the controller 200, as described below, the voltage at node 240 may be determined by either the feedback signal (V_{SUB}-V_{FB}) or the reference voltage (V_{SENSE}) 226.

[0017] The burst mode control circuit 208, 210, 228 causes the MOSFET switch 211 to open, suspending current flow through the primary winding, when the feedback signal (FB) indicates that the load on the transformer's main secondary winding has fallen below a predetermined minimum load threshold (V_{BRL}). In operation, the Schmitt trigger comparator 208 compares the output of the voltage subtracter 228 (V_{SUB}-V_{FB}) with a voltage reference 210. When the voltage subtracter output (V_{SUB}-V_{FB}) falls below the voltage reference value V_{BRL} (*i.e.,* the turn-on voltage for the Schmitt trigger comparator 208), a logic high signal is output from the comparator 208 to the logic gate 215 in the switching circuit 202, which bypasses the switching pulse (fs) and causes the MOSFET switch 211 to open. When the voltage subtracter output (V_{SUB}-V_{FB}) then rises above V_{BRH} (*i.e.,* the turn-off voltage for the Schmitt trigger comparator 208), the switching pulse (fs) will turn back on. This operation will continue, with the switching pulse (fs) turning on and off on a periodic basis, until the power supply is turned off or the load increases such that V_{SUB}-V_{FB} remains above V_{BRH}.

[0018] Figs. 3 and 4 respectively illustrate a four-mode and a three-mode operation for the multi-mode controller 200 of Fig. 2. The multi-mode controller 200 may, for example, be configured to operate as either a four-mode or a three-mode controller by selecting appropriate values for the Zener diode 218, voltage subtracter 228 and burst mode voltage reference (V_{BR}) 210. Specifically, the four-mode operation 300 shown in Fig. 3 may be provided by selecting design parameters for the multi-mode controller 200 such that V_{SUB}-V_{ZENER}>V_{BRL}, where V_{ZENER} is the break-down voltage for the Zener diode 218. The three-mode operation 400 shown in Fig. 4 may be provided by selecting design parameters such that V_{SUB}-V_{ZENER}<V_{BRL}.

[0019] With reference first to Fig. 3, this figure 300 includes two graphs that respectively depict how the multi-mode controller 200 of Fig. 2 causes the switching frequency (fs) and the peak current to vary in relation to the load during four operational modes. During operational mode 1, which is used for the heaviest loads, the switching frequency varies as a function of the load and the peak current remains constant. With reference to Fig. 2, during operational mode 1 the feedback signal voltage (V_{FB}), which is inversely proportional to the load, is less than the Zener diode 218 breakdown voltage (*i.e.,* V_{FB}<V_{ZENER}). Thus, during mode 1, the voltage at node 230 in the frequency control circuit 204 of Fig. 2 is determined by the feedback signal (FB), and the switching frequency (fs) varies in relation to the load as shown at reference 310 in Fig. 3. Also during mode 1, the output of the voltage subtracter 228 is greater than the reference voltage (V_{SENSE}) in the current limiting circuit 206 of Fig. 2 (*i.e.,* V_{SUB}-V_{FB}>V_{SENSE}). Therefore, during mode 1, the voltage at node 240 is determined by the reference voltage (V_{SENSE}), and the peak current remains constant as shown at reference 312 in Fig. 3. Specifically, during mode 1 the switching frequency may be expressed as: fs = 1/[(Ct * V_{FB}/I_{Ct}) + T_{PULSE}].

[0020] During operational mode 2, as shown in Fig. 3, both the switching frequency and the peak current vary as a function of the load. With reference to Fig. 2, during operational mode 2 the feedback signal voltage (V_{FB}) remains less than the Zener diode 218 breakdown voltage (*i.e.,* V_{FB}<V_{ZENER}), and thus the switching frequency (fs) varies in relation to the load as shown at reference 314 in Fig. 3. Specifically, during operational mode 2 the switching frequency may be expressed as: fs = 1/[(Ct * V_{FB}/I_{Ct}) + T_{PULSE}]. Also during operational mode 2, the output of the voltage subtracter 228 (V_{SUB}-V_{FB}) falls below the reference voltage (V_{SENSE}) in the current limiting circuit 206 (*i.e.,* V_{SUB}-V_{FB}<V_{SENSE}). Therefore, during operational mode 2, the voltage at node 240 is a function of the feedback signal (V_{SUB}-V_{FB}), and the peak current varies in relation to the load as shown at reference 316 in Fig. 3.

[0021] During operational mode 3, as shown in Fig. 3, the peak current varies as a function of the load and the switching frequency (fs) remains constant. With reference to Fig. 2, during operational mode 3 the feedback signal voltage (V_{FB}) becomes greater than the breakdown voltage of the Zener diode 218 (*i.e.,* V_{FB}>V_{ZENER}), and thus the Zener diode 218 clamps the voltage at node 230 at its breakdown voltage (V_{ZENER}). This causes the switching frequency (fs) to remain constant as shown at reference 318 in Fig. 3. Specifically, during mode 3 the switching frequency may be expressed as: fs = 1/[(Ct * $V_{ZENER}/(I_{Ct})$ + T_{PULSE}]. Also during operational mode 3, the output of the voltage subtracter 228 (V_{SUB}-V_{FB}) remains less than the reference voltage (V_{SENSE}) (*i.e.*, V_{SUB}-V_{FB}<V_{SENSE}). Therefore, the peak current varies in relation to the load as shown at reference 320 in Fig. 3.

[0022] When the load falls below a minimum load threshold, the multi-mode controller enters burst mode, which is shown as operational mode 4 in Fig. 3. With reference to Fig. 2, during operational mode 4 (*i.e.,* burst mode) the output of the voltage subtracter 228 (V_{SUB}-V_{FB}) falls below V_{BRL} (*i.e.*, V_{SUB}-V_{FB}<V_{BRL}). This causes the MOSFET switch 211 in Fig. 2 to open, resulting in no switching pulse (fs) or current flow through the primary winding as shown at references 322 and 324 in Fig. 3. When the voltage subtracter output (V_{SUB}-V_{FB}) rises above V_{BRH}, the switching pulse (fs) will turn back on.

[0023] With reference now to Fig. 4, this figure 400 includes two graphs that respectively depict how the multi-mode controller 200 of Fig. 2 causes the switching frequency (fs) and the peak current to vary in relation to the load during three operational modes. The three-mode operation illustrated in Fig. 4 is similar to the four-mode operation described above with reference to Fig. 3, except that as the load decreases, the multi-mode controller 102 transitions directly from mode 2 to burst mode. As explained above, the three-mode operation of the multi-mode controller 200 illustrated in Fig. 4 may be achieved by selecting design parameters such that V_{SUB}-V_{ZENER}<V_{BRL}.

[0024] Fig. 5 is a diagram of another example multi-mode controller 500, which may be used in the switching mode power supply 100 of Fig. 1. This example is similar to the multi-mode controller 200 described above with reference to Fig. 2, except that the Zener diode is replaced with a voltage reference (V_{OFFSET}) 502 and a signal choice circuit (represented in the diagram by two diodes 504, 506) to modify the operation of the frequency control circuit 508. In addition, the direction of the signal choice circuit 509, 511 is reversed to modify the operation of the current limiting circuit 513. Specifically, in this example 500 the threshold voltage at node 510, which controls the switching frequency of the MOSFET switch 512, is determined by either the feedback signal (FB) or the voltage reference (V_{OFFSET}) 502, depending on the operating mode of the controller 500. That is, the signal choice circuit 504, 506 causes the voltage at node 510 to be the larger of the voltage reference (V_{OFFSET}) 502 or the feedback signal voltage (V_{FB}). Also, the threshold voltage at node 516, which controls the peak current limit, is determined by the larger of the feedback signal (V_{SUB}-V_{FB}) or the voltage reference (V_{SENSE}) 520.

[0025] Figs. 6 and 7 respectively illustrate a four-mode and a three-mode operation for the multi-mode controller 500 of Fig. 5. The multimode controller 500 may, for example, be configured to operate as either a four-more or a three-mode controller by selecting appropriate values for the voltage reference (V_{OFFSET}) 502, voltage subtracter 514 and voltage reference (V_{SENSE}) 520. Specifically, the three-mode operation 700 shown in Fig. 7 may be provide by selecting design parameters such that V_{SUB}-V_{OFFSET} = V_{SENSE}. The four-mode operation 600 shown in Fig. 6 may be provided by selecting design parameters such that V_{SUB}-V_{OFFSET} > V_{SENSE}

[0026] With reference first to Fig. 6, this figure 600 includes two graphs that respectively depict how the multi-mode controller 500 of Fig. 5 causes the switching frequency (fs) and peak current to vary in relation to the load during four operational modes. During operational mode 1, which is used for the heaviest loads, the peak current varies as a function of the load and the switching frequency remains constant. With reference to Fig. 2, during operational mode 1 the voltage of the feedback signal (V_{FB}), which is inversely proportional to the load, is less than the voltage reference (V_{OFFSET}). Thus, during mode 1, the voltage at node 510 is clamped at a constant value by the voltage reference (V_{OFFSET}) and the switching frequency (fs) remains constant as shown at reference 610 in Fig. 6. Specifically, during mode 1 the switching frequency may be expressed as: $fs = 1/[(Ct * V_{OFFSET}/I_{Ct}) + T_{PULSE}]$. Also during operational mode 1, the output of the voltage subtracter (V_{SUB}-V_{FB}) 514 is greater than the reference voltage (V_{SENSE}) 520 (*i.e.,* V_{SUB}-V_{FB}>V_{SENSE}). Therefore, during mode 1, the voltage at node 516 in the current limiting circuit is a function of the feedback signal (V_{SUB}-V_{FB}), and the peak current varies in relation to the load as shown at reference 612 in Fig. 6.

[0027] During operational mode 2, as shown in Fig. 6, both the switching frequency (fs) and the peak current vary as a function of the load. With reference to Fig. 5, during operational mode 2 the voltage of the feedback signal (V_{FB}) rises above the voltage reference (V_{OFFSET}), and thus the voltage at node 510 is determined by the feedback signal (FB), causing the switching frequency (fs) to vary in relation to the load as shown at reference 614 in Fig. 6. Specifically, during operational mode 2 the switching frequency (fs) may be expressed as: $fs = 1/[(Ct * V_{OFFSET}/I_{Ct})+ T_{PULSE}]$. Also during mode 2, the output of the voltage subtracter 514 (V_{SUB}-V_{FB}) remains greater than the reference voltage (V_{SENSE}) 520, and thus the peak current continues to vary in relation to the load as shown at reference 616 in Fig. 6.

[0028] During operational mode 3, as shown in Fig. 6, the switching frequency (fs) varies as a function of the load and the peak current is constant. With reference to Fig. 5, during operational mode 3 the voltage of the feedback signal (V_{FB}) remains above the voltage reference (V_{OFFSET}), and thus the switching frequency (fs) continues to vary in relation to the load as shown at reference 618 in Fig. 6. Also during operational mode 3, the output of the voltage subtracter (V_{SUB}-V_{FB}) 514 falls below the voltage reference (V_{SENSE}) 520, and thus the peak current is clamped at a constant value by the voltage reference (V_{SENSE}) 520 as shown at reference 620 in Fig. 6.

[0029] When the load falls below a minimum load threshold, the multi-mode controller enters burst mode, which is shown as operational mode 4 in Fig. 6. With reference to Fig. 5, during operational mode 4 (*i.e.,* burst mode) the output of the voltage subtracter 514 falls below the voltage reference value V_{BRL} 522 (*i.e.,* V_{SUB}-V_{FB}<V_{SRL}). This causes the MOSFET switch 512 to open, resulting in no switching pulse (fs) or current through the primary winding as shown at references 622 and 624 in Fig. 6. When the voltage subtracter output (V_{SUB}-V_{FB}) rises above V_{BRH}, the switching pulse (fs) will turn back on.

[0030] With reference now to Fig. 7, this figure 700 includes two graphs that respectively depict how the multi-mode controller 500 of Fig. 5 causes the switching frequency (fs) and the peak current to vary in relation to the load during three operational modes. The three-mode operation illustrated in Fig. 7 is the similar to the four-mode operation described above with reference to Fig. 6, without a mode during which both the switching frequency (fs) and the peak current are simultaneously varying as a function of the load. In other words, operational mode 2 of Fig. 6 is not provided in the three-mode operation shown in Fig. 7. As explained above, the three-mode operation of the multi-mode controller 500, as illustrated in Fig. 7, may be implemented by selecting design parameters such that V_{SUB}-V_{OFFSET} = V_{SENSE}.

[0031] This written description uses examples to disclose the invention, including the best mode, and also to enable a person skilled in the art to make and use the invention. The scope of the invention is defined by the claims.

[0032] The following statements provide general expressions of the disclosure herein.

A. A switching mode power supply, comprising:

  a transformer having a primary winding and a secondary winding to supply power to a load;
  a feedback circuit that generates a feedback signal that varies in relation to the load on the secondary winding;

a switching circuit coupled to the primary winding to control current flow through the primary winding;
a frequency control circuit that controls a switching frequency of the switching circuit based on the feedback signal; and
a current limiting circuit that limits current flow through the primary winding by causing the switching circuit to suspend current flow through the primary winding when the current reaches a peak current limit that is set based on the feedback signal.

B. The switching mode power supply of statement A, further comprising:

a burst mode control circuit that bypasses the frequency control circuit and the current limiting circuit to control operation of the switching circuit when the load on the secondary winding falls below a minimum load threshold.

C. The switching mode power supply of statement B, wherein the switching mode power supply operates in three modes:

a first mode during which the switching frequency varies as a function of the feedback signal and the peak current limit is constant;
a second mode during which both the switching frequency and the peak current limit vary as a function of the feedback signal; and
a burst mode during which operation of the frequency control circuit and the current limiting circuit is suspended.

D. The switching mode power supply of statement C, wherein the switching mode power supply transitions from the first mode to the second mode to the burst mode as the load on the secondary winding decreases.

E. The switching mode power supply of statement B, wherein the switching mode power supply operates in four modes:

a first mode during which the switching frequency varies as a function of the feedback signal and the peak current limit is constant;
a second mode during which both the switching frequency and the peak current limit vary as a function of the feedback signal;
a third mode during which the peak current limit varies as a function of the feedback signal and the switching frequency is constant; and
a burst mode during which operation of the frequency control circuit and the current limiting circuit is suspended.

F. The switching mode power supply of statement E, wherein the switching mode power supply transitions from the first mode to the second mode to the third mode to the burst mode as the load on the secondary winding decreases.

G. The switching mode power supply of statement E, wherein the switching mode power supply transitions from the third mode to the second mode to the first mode to the burst mode as the load on the secondary winding decreases.

H. The switching mode power supply of statement B, wherein the switching mode power supply operates in three modes:

a first mode during which the peak current limit varies as a function of the feedback signal and the switching frequency is constant;
a second mode during which the switching frequency varies as a function of the feedback signal and the peak current limit is constant; and
a burst mode during which operation of the frequency control circuit and the current limiting circuit is suspended.

I. The switching mode power supply of statement H, wherein the switching mode power supply transitions from the first mode to the second mode to the burst mode as the load on the secondary winding decreases.

J. The switching mode power supply of statement A, wherein the frequency control circuit includes a voltage-controlled oscillator circuit that controls the switching frequency of the switching circuit as a function of a threshold voltage.

K. The switching mode power supply of statement J, wherein the threshold voltage is determined by the feedback signal during at least one operational mode of the switching mode power supply, and wherein the threshold voltage held constant during at least one other operational mode of the switching mode power supply.

L. The switching mode power supply of statement K, wherein the threshold voltage is held constant by a Zener diode circuit.

M. The switching mode power supply of statement K, wherein the threshold voltage is held constant by a voltage source.

N. The switching mode power supply of statement A, wherein the current limiting circuit includes a comparison circuit that controls the peak current limit as a function of a threshold voltage.

O. The switching mode power supply of statement N, wherein the threshold voltage is determined based on the feedback signal during at least one operational mode of the switching mode power supply, and wherein the threshold voltage held constant during at least one other operational mode of the switching mode power supply.

P. The switching mode power supply of statement O, wherein the threshold voltage is held constant by a voltage source.

Q. The switching mode power supply of statement B, wherein the burst mode control circuit includes a comparison circuit that suspends current flow through the secondary winding based on the feedback signal.

R. A method for controlling a switching mode power supply, comprising:

regulating an output voltage of the switching mode power supply by switching a transformer on and off at a switching frequency;
generating a feedback signal that varies in relation to a load coupled to the output voltage;
controlling the switching frequency based on the feedback signal; and
limiting a peak current through a primary winding of the transformer based on the feedback signal.

S. The method of statement R, wherein the switching mode power supply operates in three modes:

a first mode during which the switching frequency varies as a function of the feedback signal and the peak current limit is constant;
a second mode during which both the switching frequency and the peak current limit vary as a function of the feedback signal; and
a burst mode during which the switching frequency and the peak current are suspended.

T. The method of statement S, wherein the switching mode power supply transitions from the first mode to the second mode to the burst mode as the load decreases.

U. The method of statement S, wherein the switching mode power supply operates in four modes:

a first mode during which the switching frequency varies as a function of the feedback signal and the peak current limit is constant;
a second mode during which both the switching frequency and the peak current limit vary as a function of the feedback signal;
a third mode during which the peak current limit varies as a function of the feedback signal and the switching frequency is constant; and
a burst mode during which the switching frequency and the peak current limit are suspended.

V. The method of statement U, wherein the switching mode power supply transitions from the first mode to the second mode to the third mode to the burst mode as the load decreases.

W. The method of statement U, wherein the switching mode power supply transitions from the third mode to the second mode to the first mode to the burst mode as the load decreases.

X. The method of statement S, wherein the switching mode power supply operates in three modes:

a first mode during which the peak current limit varies as a function of the feedback signal and the switching frequency is constant;
a second mode during which the switching frequency varies as a function of the feedback signal and the peak current limit is constant; and
a burst mode during which the switching frequency and the peak current limit are suspended.

Y. The method of statement X, wherein the switching mode power supply transitions from the first mode to the second mode to the burst mode as the load decreases.

Z. A multi-mode controller for a switching mode power supply that includes a transformer having a primary winding and a secondary winding to supply power to a load and a feedback circuit that generates a feedback signal that varies in relation to the load on the secondary winding, the multi-mode controller comprising;

a switching circuit to be coupled to the primary winding to control current flow through the primary winding;
a frequency control circuit to control a switching frequency of the switching circuit based on the feedback signal; and
a current limiting circuit to limit current flow through the primary winding by causing the switching circuit to suspend current flow through the primary winding when the current reaches a peak current limit that is set based on the feedback signal.

ZA. The multi-mode controller of statement Z, further comprising:

a burst mode control circuit that bypasses the frequency control circuit and the current limiting circuit to control operation of the switching circuit when the load on the secondary winding falls below a minimum load threshold.

ZB. The multi-mode controller of statement ZA, wherein multi-mode controller operates in three modes:

a first mode during which the switching frequency varies as a function of the feedback signal and the peak current limit is constant;
a second mode during which both the switching frequency and the peak current limit vary as a function of the feedback signal; and
a burst mode during which operation of the frequency control circuit and the current limiting circuit is suspended.

ZC. The multi-mode controller of statement ZB, wherein the multi-mode controller transitions from the first mode to the second mode to the burst mode as the load on the secondary winding decreases.

ZD. The multi-mode controller of statement ZA, wherein the multi-mode controller operates in four modes:

a first mode during which the switching frequency varies as a function of the feedback signal and the peak current limit is constant;
a second mode during which both the switching frequency and the peak current limit vary as a function of the feedback signal;
a third mode during which the peak current limit varies as a function of the feedback signal and the switching frequency is constant; and
a burst mode during which operation of the frequency control circuit and the current limiting circuit is suspended.

ZE. The multi-mode controller of statement ZD, wherein the multi-mode controller transitions from the first mode to the second mode to the third mode to the burst mode as the load on the secondary winding decreases.

ZF. The multi-mode controller of statement ZD, wherein the multi-mode controller transitions from the third mode to the second mode to the first mode to the burst mode as the load on the secondary winding decreases.

ZG. The multi-mode controller of statement ZA, wherein the multi-mode controller operates in three modes:

a first mode during which the peak current limit varies as a function of the feedback signal and the switching frequency is constant;
a second mode during which the switching frequency varies as a function of the feedback signal and the peak current limit is constant; and
a burst mode during which operation of the frequency control circuit and the current limiting circuit is suspended.

ZH. The multi-mode controller of statement ZG, wherein the multi-mode controller transitions from the first mode to the second mode to the burst mode as the load on the secondary winding decreases.

ZI. The multi-mode controller of statement Z, wherein the frequency control circuit includes a voltage-controlled oscillator circuit that controls the switching frequency of the switching circuit as a function of a threshold voltage.

ZJ. The multi-mode controller of statement ZI, wherein the threshold voltage is determined by the feedback signal during at least one operational mode of the multi-mode controller, and wherein the threshold voltage held constant during at least one other operational mode of the multi-mode controller.

ZK. The multi-mode controller of statement ZJ, wherein the threshold voltage is held constant by a Zener diode circuit.

ZL. The multi-mode controller of statement ZJ, wherein the threshold voltage is held constant by a voltage source.

ZM. The multi-mode controller of statement Z, wherein the current limiting circuit includes a comparison circuit that controls the peak current limit as a function of a threshold voltage.

ZN. The multi-mode controller of statement ZM, wherein the threshold voltage is determined based on the feedback signal during at least one operational mode of multi-mode controller, and wherein the threshold voltage held constant during at least one other operational mode of the multi-mode controller.

ZO. The multi-mode controller of statement ZN, wherein the threshold voltage is held constant by a voltage source.

ZP. The multi-mode controller of statement ZA, wherein the burst mode control circuit includes a comparison circuit that suspends current flow through the secondary winding based on the feedback signal.

Claims

1. A multi-mode controller (102) for a switching mode power supply (100) that includes a transformer (T1) having a primary winding (110) and a secondary winding (112) to supply power to a load (116) and a feedback circuit (108) that generates a feedback signal (FB) that varies in relation to the load (116) on the secondary winding (112), the multi-mode controller (200) comprising:

   a switching circuit (202) to be coupled to the primary winding (110) to control current flow through the primary winding (110);
   a frequency control circuit (204) to control a switching frequency of the switching circuit (202); and
   a current limiting circuit (206) to limit current flow through the primary winding (110) by causing the switching circuit (202) to suspend current flow through the primary winding (110) when the current reaches a peak current limit (240) that is set based on the feedback signal (FB);
   characterized in that the switching frequency is based on the feedback signal (FB);
   wherein during at least one mode, the switching frequency (fs) decreases as the load (116) becomes lighter;
   and wherein during at least one mode, the peak current limit (PEAK CURRENT) decreases as the load (116) becomes lighter.

2. The multi-mode controller (200) of claim 1, further comprising:

   a burst mode control circuit (208, 210) that bypasses the frequency control circuit (204) and the current limiting circuit (206) to control operation of the switching circuit (202) when the load (116) on the secondary winding (112) falls below a minimum load threshold (V_{BRL}).

3. The multi-mode controller (102) of claim 2, wherein the multi-mode controller (102) operates in three modes (400):

   a first mode during which the switching frequency varies as a function of the feedback signal (FB) and the peak current limit is constant;
   a second mode during which both the switching frequency and the peak current limit vary as a function of the feedback signal (FB); and
   a burst mode during which operation of the frequency control circuit (204) and the current limiting circuit (206) is suspended;
   wherein, optionally, the multi-mode controller (102) transitions from the first mode to the second mode to the burst mode as the load (116) on the secondary winding (112) decreases.

4. The multi-mode controller (102) of claim 2, wherein the multi-mode controller (102) operates in four modes (300):

   a first mode during which the switching frequency varies as a function of the feedback signal (FB) and the peak current limit is constant;
   a second mode during which both the switching frequency and the peak current limit vary as a function of the feedback signal (FB);
   a third mode during which the peak current limit varies as a function of the feedback signal (FB) and the switching frequency is constant;
   and a burst mode during which operation of the frequency control circuit (204) and the current limiting circuit (206) is suspended;
   wherein, optionally, the multi-mode controller (102) transitions from the first mode to the second mode to the third mode to the burst mode as the load (116) on the secondary winding (112) decreases.

5. The multi-mode controller (102) of claim 4, wherein the multi-mode controller (102) transitions from the third mode to the second mode to the first mode to the burst mode as the load (116) on the secondary winding (112) decreases.

6. The multi-mode controller (102) of claim 2, wherein the multi-mode controller (102) operates in three modes (700):

   a first mode during which the peak current limit varies as a function of the feedback signal (FB) and the switching frequency is constant;
   a second mode during which the switching frequency varies as a function of the feedback signal (FB) and the peak current limit is constant;
   and a burst mode during which operation of the frequency control circuit (204) and the current limiting circuit (206) is suspended;
   wherein, optionally, the multi-mode controller (102) transitions from the first mode to the second mode to the burst mode as the load (116) on the secondary winding (112) decreases.

7. The multi-mode controller (200) of claim 1, wherein the frequency control circuit (204) includes a voltage-controlled oscillator circuit (213, 214, 221, 216) that controls the switching frequency of the switching circuit (202) as a function of a threshold voltage (230).

8. The multi-mode controller (200) of claim 7, wherein the threshold voltage (230) is determined by the feedback signal (FB) during at least one operational mode of the multi-mode controller (102), and wherein

the threshold voltage (230) held constant during at least one other operational mode of the multimode controller (200);
wherein, optionally, the threshold voltage (230) is held constant by a Zener diode circuit (218).

9. The multi-mode controller (500) of claim 8, wherein the threshold voltage (510) is held constant by a voltage source (502).

10. The multi-mode controller (200) of claim 1, wherein the current limiting circuit (206) includes a comparison circuit (224) that controls the peak current limit as a function of a threshold voltage (240).

11. The multi-mode controller (200) of claim 10, wherein the threshold voltage (240) is determined based on the feedback signal (FB) during at least one operational mode of multi-mode controller (200), and wherein the threshold voltage (240) held constant during at least one other operational mode of the multi-mode controller (200).

12. The multi-mode controller (500) of claim 11, wherein the threshold voltage (516) is held constant by a voltage source (520).

13. The multi-mode controller (200) of claim 2, wherein the burst mode control circuit (208, 210) includes a comparison circuit (208) that suspends current flow through the secondary winding (112) based on the feedback signal (FB).

14. A switching mode power supply (100), comprising:

a transformer (T1) having a primary winding (110) and a secondary winding (112) to supply power to a load (116);
a feedback circuit (108) that generates a feedback signal (FB) that varies in relation to the load (116) on the secondary winding (112); and
a multimode controller (102) for a switching mode power supply (100) according to any one of claims 1 to 13; wherein:

the switching circuit (202) is coupled to the primary winding (110) to control current flow through the primary winding (110);
the frequency control circuit (204) controls a switching frequency of the switching circuit (202) based on the feedback signal (FB);
and the current limiting circuit (206) limits current flow through the primary winding (110) by causing the switching circuit to suspend current flow through the primary winding (110) when the current reaches a peak current limit (240) that is set based on the feedback signal (FB);

wherein during at least one mode, the switching frequency (fs) decreases as the load (116) becomes lighter;
and wherein during at least one mode, the peak current limit (PEAK CURRENT) decreases as the load (116) becomes lighter.

15. A method for controlling a switching mode power supply (100), comprising:

regulating an output voltage (V_{OUT}) of the switching mode power supply (100) by switching a transformer (T1) on and off at a switching frequency;
generating a feedback signal (FB) that varies in relation to a load (116) coupled to the output voltage (V_{OUT});
controlling the switching frequency (fs); and
limiting a peak current through a primary winding (110) of the transformer (T1) based on the feedback signal (FB);
characterized in that the switching frequency (fs) is controlled based on the feedback signal (FB);
wherein during at least one mode, the switching frequency (fs) decreases as the load (116) becomes lighter;
and wherein during at least one mode, the peak current limit (PEAK CURRENT) decreases as the load (116) becomes lighter.

Patentansprüche

1. Mehrfachmodussteuerungseinheit (102) für ein Schaltmodusnetzteil (100), das einen Transformator (T1) mit einer Primärwicklung (110) und einer Sekundärwicklung (112), um einer Last (116) Leistung zuzuführen, und eine Rückkopplungsschaltung (108), die ein Rückkopplungssignal (FB) erzeugt, das in Bezug auf die Last (116) auf der Sekundärwicklung (112) variiert, umfasst, wobei die Mehrfachmodussteuerungseinheit Folgendes umfasst:

einen mit der Primärwicklung (110) zu koppelnden Schaltstromkreis (202), um den Stromfluss durch die Primärwicklung (110) hindurch zu steuern;
eine Frequenzsteuerschaltung (204), um eine Schaltfrequenz des Schaltstromkreises (202) zu steuern; und
eine Strombegrenzungsschaltung (206), um den Stromfluss durch die Primärwicklung (110) zu begrenzen, indem der Schaltstromkreis (202) veranlasst wird, den Stromfluss durch die Primärwicklung (110) hindurch zu unterbrechen,

wenn der Strom einen Spitzenstromgrenzwert (240) erreicht, der auf Basis des Rückkopplungssignals (FB) eingestellt ist;
dadurch gekennzeichnet, dass
die Schaltfrequenz auf dem Rückkopplungssignal (FB) basiert;
worin, während mindestens einer Betriebsart, die Schaltfrequenz (fs) abnimmt, wenn die Last (116) geringer wird; und
worin, während mindestens einer Betriebsart, der Spitzenstromgrenzwert (PEAK CURRENT) abnimmt, wenn die Last (116) geringer wird.

2. Mehrfachmodusteuerungseinheit (200) nach Anspruch 1, ferner umfassend:

eine Burst-Modus-Steuerschaltung (208, 210), welche die Frequenzsteuerschaltung (204) und die Strombegrenzungsschaltung (206) umgeht, um den Betrieb des Schaltstromkreises (202) zu steuern, wenn die Last (116) auf der Sekundärwicklung (112) unter einen Minimallastschwellenwert (V_{BRL}) fällt.

3. Mehrfachmodussteuerungseinheit (102) nach Anspruch 2, worin die Mehrfachmodussteuerungseinheit (102) in drei Betriebsarten (400) arbeitet:

einem ersten Modus, während dem die Schaltfrequenz als eine Funktion des Rückkopplungssignals (FB) variiert und der Spitzenstromgrenzwert konstant ist;
einem zweiten Modus, während dem sowohl die Schaltfrequenz als auch der Spitzenstromgrenzwert als eine Funktion des Rückkopplungssignals (FB) variieren; und
einem Burst-Modus, während dem der Betrieb der Frequenzsteuerschaltung (204) und der Strombegrenzungsschaltung (206) unterbrochen wird;
worin die Mehrfachmodussteuerungseinheit (102) wahlweise vom ersten Modus in den zweiten Modus und in den Burst-Modus übergeht, wenn die Last (116) auf der Sekundärwicklung (112) abnimmt.

4. Mehrfachmodussteuerungseinheit (102) nach Anspruch 2, worin die Mehrfachmodussteuerungseinheit (102) in vier Betriebsarten (300) arbeitet:

einem ersten Modus, während dem die Schaltfrequenz als eine Funktion des Rückkopplungssignals (FB) variiert und der Spitzenstromgrenzwert konstant ist;
einem zweiten Modus, während dem sowohl die Schaltfrequenz als auch der Spitzenstromgrenzwert als eine Funktion des Rückkopplungssignals (FB) variieren;
einem dritten Modus, während dem der Spitzenstromgrenzwert als eine Funktion des Rückkopplungssignals (FB) variiert und die Schaltfrequenz konstant ist;
und einem Burst-Modus, während dem der Betrieb der Frequenzsteuerschaltung (204) und der Strombegrenzungsschaltung (206) unterbrochen wird;
worin die Mehrfachmodussteuerungseinheit (102) vom ersten Modus in den zweiten Modus und in den dritten Modus übergeht, wenn die Last (116) auf der Sekundärwicklung (112) abnimmt.

5. Mehrfachmodussteuerungseinheit (102) nach Anspruch 4, worin die Mehrfachmodussteuerungseinheit (102) vom dritten Modus in den zweiten Modus, in den ersten Modus und in den Burst-Modus übergeht, wenn die Last (116) auf der Sekundärwicklung (112) abnimmt.

6. Mehrfachmodussteuerungseinheit (102) nach Anspruch 2, worin die Mehrfachmodussteuerungseinheit (102) in drei Betriebsarten (700) arbeitet:

einem ersten Modus, während dem der Spitzenstromgrenzwert als eine Funktion des Rückkopplungssignals (FB) variiert und die Schaltfrequenz konstant ist;
einem zweiten Modus, während dem die Schaltfrequenz als eine Funktion des Rückkopplungssignals (FB) variiert und der Spitzenstromgrenzwert konstant ist; und
einem Burst-Modus, während dem der Betrieb der Frequenzsteuerschaltung (204) und der Strombegrenzungsschaltung (206) unterbrochen wird;
worin die Mehrfachmodussteuerungseinheit (102) vom ersten Modus in den zweiten Modus und in den Burst-Modus übergeht, wenn die Last (116) auf der Sekundärwicklung (112) abnimmt.

7. Mehrfachmodussteuerungseinheit (200) nach Anspruch 1, worin die Frequenzsteuerschaltung (204) eine spannungsgesteuerte Oszillatorschaltung (213, 214, 221, 216) umfasst, welche die Schaltfrequenz des Schaltstromkreises (202) als eine Funktion der Schwellenwertspannung (230) steuert.

8. Mehrfachmodussteuerungseinheit (200) nach Anspruch 7, worin die Schwellenwertspannung (230) durch das Rückkopplungssignal (FB) während mindestens einer Betriebsart der Mehrfachmodussteuerungseinheit (102) bestimmt wird, und worin die Schwellenwertspannung (230) während mindestens einer weiteren Betriebsart der Mehrfachmodussteuerungseinheit (200) konstant gehalten wird; worin die Schwellenwertspannung (230) durch eine Zenerdiodenschaltung (218) wahlweise konstant gehalten wird.

9. Mehrfachmodussteuerungseinheit (500) nach Anspruch 8, worin die Schwellenwertspannung (510) durch eine Spannungsquelle (502) konstant gehalten wird.

10. Mehrfachmodussteuerungseinheit (200) nach Anspruch 1, worin die Strombegrenzungsschaltung (206) eine Vergleichsschaltung (224) umfasst, die den Spitzenstromgrenzwert als eine Funktion einer Schwellenwertspannung (240) steuert.

11. Mehrfachmodussteuerungseinheit (200), worin die Schwellenwertspannung (240) auf Basis des Rückkopplungssignals (FB) während mindestens einer Betriebsart von Mehrfachmodussteuerungseinheit (200) bestimmt wird, und worin die Schwellenwertspannung (240) während mindestens einer weiteren Betriebsart der Mehrfachmodussteuerungseinheit (200) konstant gehalten wird.

12. Mehrfachmodussteuerungseinheit (500) nach Anspruch 11, worin die Schwellenwertspannung (516) durch eine Spannungsquelle (520) konstant gehalten wird.

13. Mehrfachmodussteuerungseinheit (200) nach Anspruch 2, worin die Burst-Modus-Steuerschaltung (208, 210) eine Vergleichsschaltung (208) umfasst, die den Stromfluss durch die Sekundärwicklung (112) auf Basis des Rückkopplungssignals (FB) unterbricht.

14. Schaltmodusnetzteil (100), umfassend:

einen Transformator (T1) mit einer Primärwicklung (110) und einer Sekundärwicklung (112), um einer Last (116) Leistung zuzuführen;
eine Rückkopplungsschaltung (108), die ein Rückkopplungssignal (FB) erzeugt, das in Bezug auf die Last (116) auf der Sekundärwicklung (112) variiert; und
eine Mehrfachmodussteuerungseinheit (102) für ein Schaltmodusnetzteil (100) gemäß einem der Ansprüche 1 bis 13, worin:

der Schaltstromkreis (202) mit der Primärwicklung (110) gekoppelt ist, um den Stromfluss durch die Primärwicklung (110) hindurch zu steuern;
die Frequenzsteuerschaltung (204) eine Schaltfrequenz des Schaltstromkreises (202) auf Basis des Rückkopplungssignals (FB) steuert;
und die Strombegrenzungsschaltung (206) den Stromfluss durch die Primärwicklung (110) hindurch begrenzt, indem sie den Schaltstromkreis veranlasst, den Stromfluss durch die Primärwicklung (110) hindurch zu unterbrechen, wenn der Strom einen Spitzenstromgrenzwert (240) erreicht, der auf Basis des Rückkopplungssignals (FB) eingestellt ist;
worin, während mindestens einer Betriebsart, die Schaltfrequenz (fs) abnimmt, wenn die Last (116) geringer wird; und
worin, während mindestens einer Betriebsart, der Spitzenstromgrenzwert (PEAK CURRENT) abnimmt, wenn die Last (116) geringer wird.

15. Verfahren für das Steuern eines Schaltmodusnetzteils (100), umfassend:

Regeln einer Ausgangsspannung (V_{OUT}) des Schaltmodusnetzteils (100) durch
Ein- und Aus-Schalten eines Transformators (T1) bei einer Schaltfrequenz;
Erzeugen eines Rückkopplungssignals (FB), das in Bezug auf eine Last (116) variiert, die mit der Ausgangsspannung (V_{OUT}) gekoppelt ist;
Steuern der Schaltfrequenz (fs); und
Begrenzen eines Spitzenstroms durch eine Primärwicklung (110) des Transformators (T1) auf Basis des Rückkopplungssignals (FB);
dadurch gekennzeichnet, dass die Schaltfrequenz (fs) auf Basis des Rückkopplungssignals (FB) gesteuert wird;
worin, während mindestens einer Betriebsart, die Schaltfrequenz (fs) abnimmt, wenn die Last (116) geringer wird;
und worin, während mindestens einer Betriebsart, der Spitzenstromgrenzwert (PEAK CURRENT) abnimmt, wenn die Last (116) geringer wird.

Revendications

1. Contrôleur multimode (102) pour une alimentation à découpage (100) qui comprend un transformateur (T1) comportant un enroulement primaire (110) et un enroulement secondaire (112) pour alimenter une charge (116) et un circuit de rétroaction (108) qui génère un signal de rétroaction (FB) qui varie en relation avec la charge (116) sur l'enroulement secondaire (112), le contrôleur multimode (200) comprenant :

un circuit de commutation (202) à coupler à l'enroulement primaire (110) pour commander la circulation de courant à travers l'enroulement primaire (110) ;
un circuit de commande de fréquence (204) pour

commander une fréquence de commutation du circuit de commutation (202) ; et
un circuit de limitation de courant (206) pour limiter la circulation de courant à travers l'enroulement primaire (110) en faisant en sorte que le circuit de commutation (202) suspende la circulation de courant à travers l'enroulement primaire (110) lorsque le courant atteint une limite de courant crête (240) qui est établie sur la base du signal de rétroaction (FB) ;
caractérisé en ce que la fréquence de commutation est basée sur le signal de rétroaction (FB) ;
dans lequel, dans au moins un mode, la fréquence de commutation (fs) diminue alors que la charge (116) devient plus faible ;
et dans lequel, dans au moins un mode, la limite de courant crête (PEAK CURRENT) diminue alors que la charge (116) devient plus faible.

2. Contrôleur multimode (200) selon la revendication 1, comprenant en outre :

un circuit de commande de mode par salve (208, 210) qui shunte le circuit de commande de fréquence (204) et le circuit de limitation de courant (206) pour commander le fonctionnement du circuit de commutation (202) lorsque la charge (116) sur l'enroulement secondaire (112) tombe au-dessous d'un seuil de charge minimum (V_{BRL}).

3. Contrôleur multimode (102) selon la revendication 2, dans lequel le contrôleur multimode (102) fonctionne dans trois modes (400) :

un premier mode dans lequel la fréquence de commutation varie en fonction du signal de rétroaction (FB) et la limite de courant crête est constante ;
un deuxième mode dans lequel la fréquence de commutation et la limite de courant crête varient toutes deux en fonction du signal de rétroaction (FB) ; et
un mode par salve dans lequel le fonctionnement du circuit de commande de fréquence (204) et du circuit de limitation de courant (206) est suspendu ;
dans lequel, en option, le contrôleur multimode (102) passe du premier mode au deuxième mode au mode par salve alors que la charge (116) sur l'enroulement secondaire (112) diminue.

4. Contrôleur multimode (102) selon la revendication 2, dans lequel le contrôleur multimode (102) fonctionne dans quatre modes (300) :

un premier mode dans lequel la fréquence de commutation varie en fonction du signal de rétroaction (FB) et la limite de courant crête est constante ;
un deuxième mode dans lequel la fréquence de commutation et la limite de courant crête varient toutes deux en fonction du signal de rétroaction (FB) ;
un troisième mode dans lequel la limite de courant crête varie en fonction du signal de rétroaction (FB) et la fréquence de commutation est constante ;
et un mode par salve dans lequel le fonctionnement du circuit de commande de fréquence (204) et du circuit de limitation de courant (206) est suspendu ;
dans lequel, en option, le contrôleur multimode (102) passe du premier mode au deuxième mode au troisième mode au mode par salve alors que la charge (116) sur l'enroulement secondaire (112) diminue.

5. Contrôleur multimode (102) selon la revendication 4, dans lequel le contrôleur multimode (102) passe du troisième mode au deuxième mode au premier mode au mode par salve alors que la charge (116) sur l'enroulement secondaire (112) diminue.

6. Contrôleur multimode (102) selon la revendication 2, dans lequel le contrôleur multimode (102) fonctionne dans trois modes (700) :

un premier mode dans lequel la limite de courant crête varie en fonction du signal de rétroaction (FB) et la fréquence de commutation est constante ;
un deuxième mode dans lequel la fréquence de commutation varie en fonction du signal de rétroaction (FB) et la limite de courant crête est constante ; et
un mode par salve dans lequel le fonctionnement du circuit de commande de fréquence (204) et du circuit de limitation de courant (206) est suspendu ;
dans lequel, en option, le contrôleur multimode (102) passe du premier mode au deuxième mode au mode par salve alors que la charge (116) sur l'enroulement secondaire (112) diminue.

7. Contrôleur multimode (200) selon la revendication 1, dans lequel le circuit de commande de fréquence (204) comprend un circuit d'oscillateur commandé par tension (213, 214, 221, 216) qui commande la fréquence de commutation du circuit de commutation (202) en fonction d'une tension de seuil (230).

8. Contrôleur multimode (200) selon la revendication 7, dans lequel la tension de seuil (230) est déterminée par le signal de rétroaction (FB) dans au moins un mode de fonctionnement du contrôleur multimode (102), et dans lequel la tension de seuil (230) est maintenue constante dans au moins un autre mode de fonctionnement du contrôleur multimode (200) ; dans lequel, en option, la tension de seuil (230) est maintenue constante par un circuit de diode Zener (218).

9. Contrôleur multimode (500) selon la revendication 8, dans lequel la tension de seuil (510) est maintenue constante par une source de tension (502).

10. Contrôleur multimode (200) selon la revendication 1, dans lequel le circuit de limitation de courant (206) comprend un circuit de comparaison (224) qui commande la limite de courant crête en fonction d'une tension de seuil (240).

11. Contrôleur multimode (200) selon la revendication 10, dans lequel la tension de seuil (240) est déterminée sur la base du signal de rétroaction (FB) dans au moins un mode de fonctionnement du contrôleur multimode (200), et dans lequel la tension de seuil (240) est maintenue constante dans au moins un autre mode de fonctionnement du contrôleur multimode (200).

12. Contrôleur multimode (500) selon la revendication 11, dans lequel la tension de seuil (516) est maintenue constante par une source de tension (520).

13. Contrôleur multimode (200) selon la revendication 2, dans lequel le circuit de commande de mode par salve (208, 210) comprend un circuit de comparaison (208) qui suspend la circulation de courant à travers l'enroulement secondaire (112) sur la base du signal de rétroaction (FB).

14. Alimentation à découpage (100), comprenant :

un transformateur (T1) comportant un enroulement primaire (110) et un enroulement secondaire (112) pour alimenter une charge (116) ;
un circuit de rétroaction (108) qui génère un signal de rétroaction (FB) qui varie en relation avec la charge (116) sur l'enroulement secondaire (112) ; et
un contrôleur multimode (102) pour une alimentation à découpage (100) selon l'une quelconque des revendications 1 à 13 ; dans lequel :

le circuit de commutation (202) est couplé à l'enroulement primaire (110) pour commander la circulation de courant à travers l'enroulement primaire (110) ;
le circuit de commande de fréquence (204) commande une fréquence de commutation du circuit de commutation (202) sur la base du signal de rétroaction (FB) ;
et le circuit de limitation de courant (206) limite la circulation de courant à travers l'enroulement primaire (110) en faisant en sorte que le circuit de commutation suspende la circulation de courant à travers l'enroulement primaire (110) lorsque le courant atteint une limite de courant crête (240) qui est établie sur la base du signal de rétroaction (FB) ;
dans lequel, dans au moins un mode, la fréquence de commutation (fs) diminue alors que la charge (116) devient plus faible ;
et dans lequel, dans au moins un mode, la limite de courant crête (PEAK CURRENT) diminue alors que la charge (116) devient plus faible.

15. Procédé pour commander une alimentation à découpage (100), comprenant :

la régulation d'une tension de sortie (V_{OUT}) de l'alimentation à découpage (100) en activant et désactivant un transformateur (T1) à une fréquence de commutation ;
la génération d'un signal de rétroaction (FB) qui varie en relation avec une charge (116) couplée à la tension de sortie (V_{OUT}) ;
la commande de la fréquence de commutation (fs) ; et
la limitation d'un courant crête à travers un enroulement primaire (110) du transformateur (T1) sur la base du signal de rétroaction (FB) ;
caractérisé en ce que la fréquence de commutation (fs) est commandée sur la base du signal de rétroaction (FB) ;
dans lequel, dans au moins un mode, la fréquence de commutation (fs) diminue alors que la charge (116) devient plus faible ;
et dans lequel, dans au moins un mode, la limite de courant crête (PEAK CURRENT) diminue alors que la charge (116) devient plus faible.

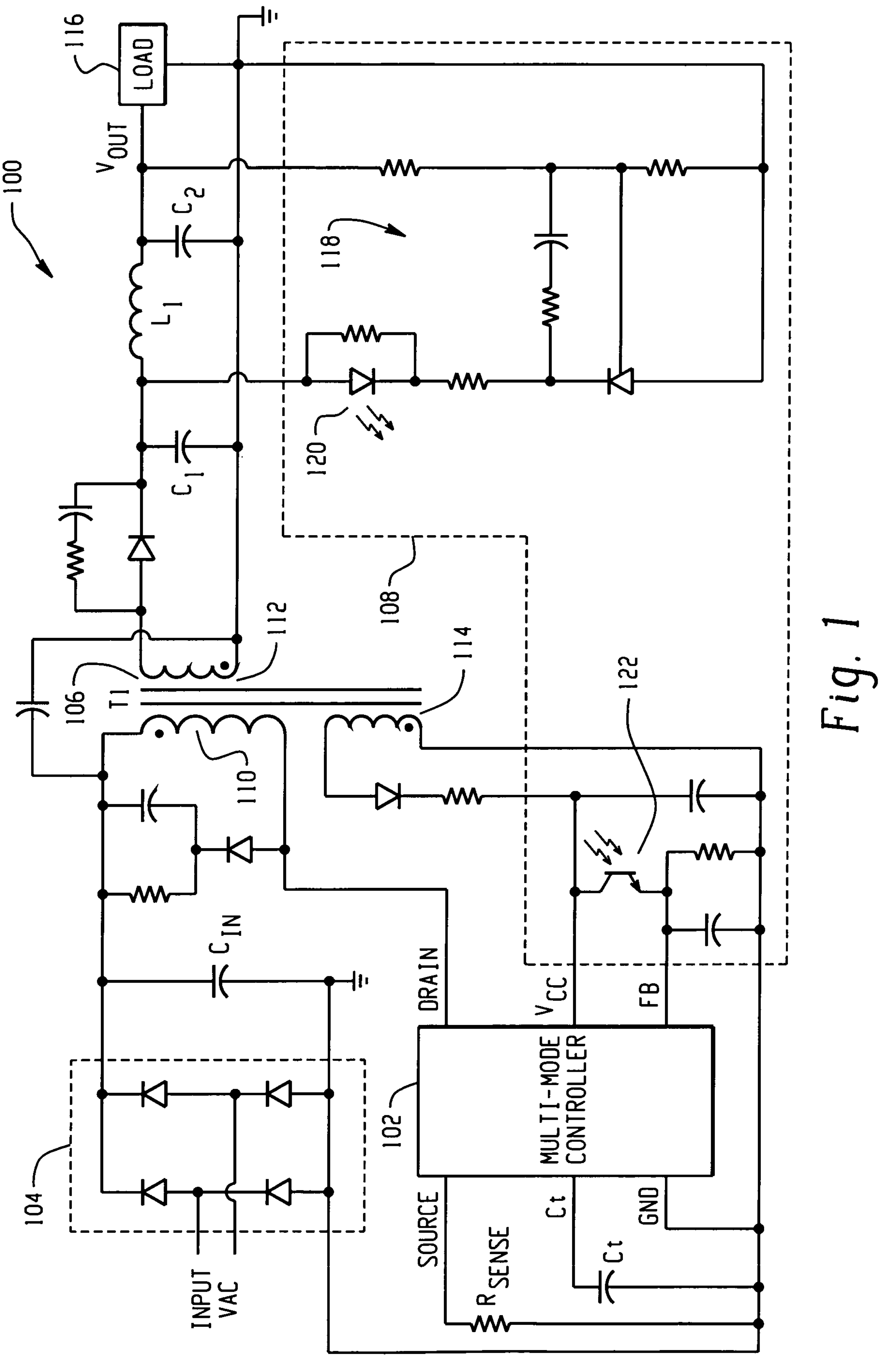
100
116
LOAD
V_OUT
C_2
L_1
C_1
118
120
112
114
106
T1
110
108
122
C_IN
DRAIN
V_CC
FB
MULTI-MODE CONTROLLER
102
104
SOURCE
Ct
GND
R_SENSE
Ct
INPUT VAC

Fig. 1

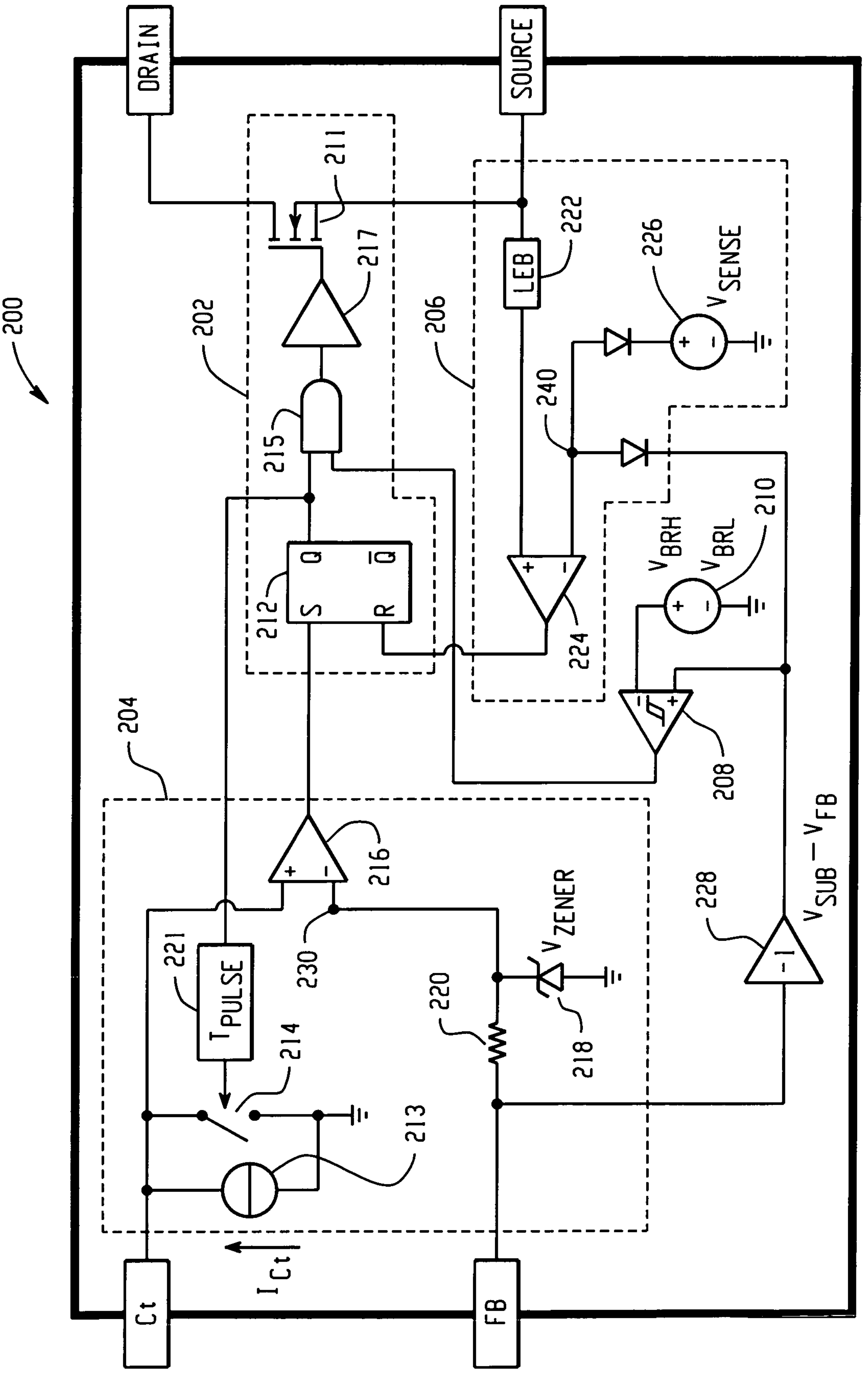
200
DRAIN
SOURCE
202
211
217
215
212
S
Q
R
Q̄
206
222
LEB
226
V_{SENSE}
240
224
V_{BRH}
V_{BRL}
210
208
204
216
230
221
T_{PULSE}
214
213
220
218
V_{ZENER}
228
-1
$V_{SUB} - V_{FB}$
I_{Ct}
Ct
FB

Fig. 2

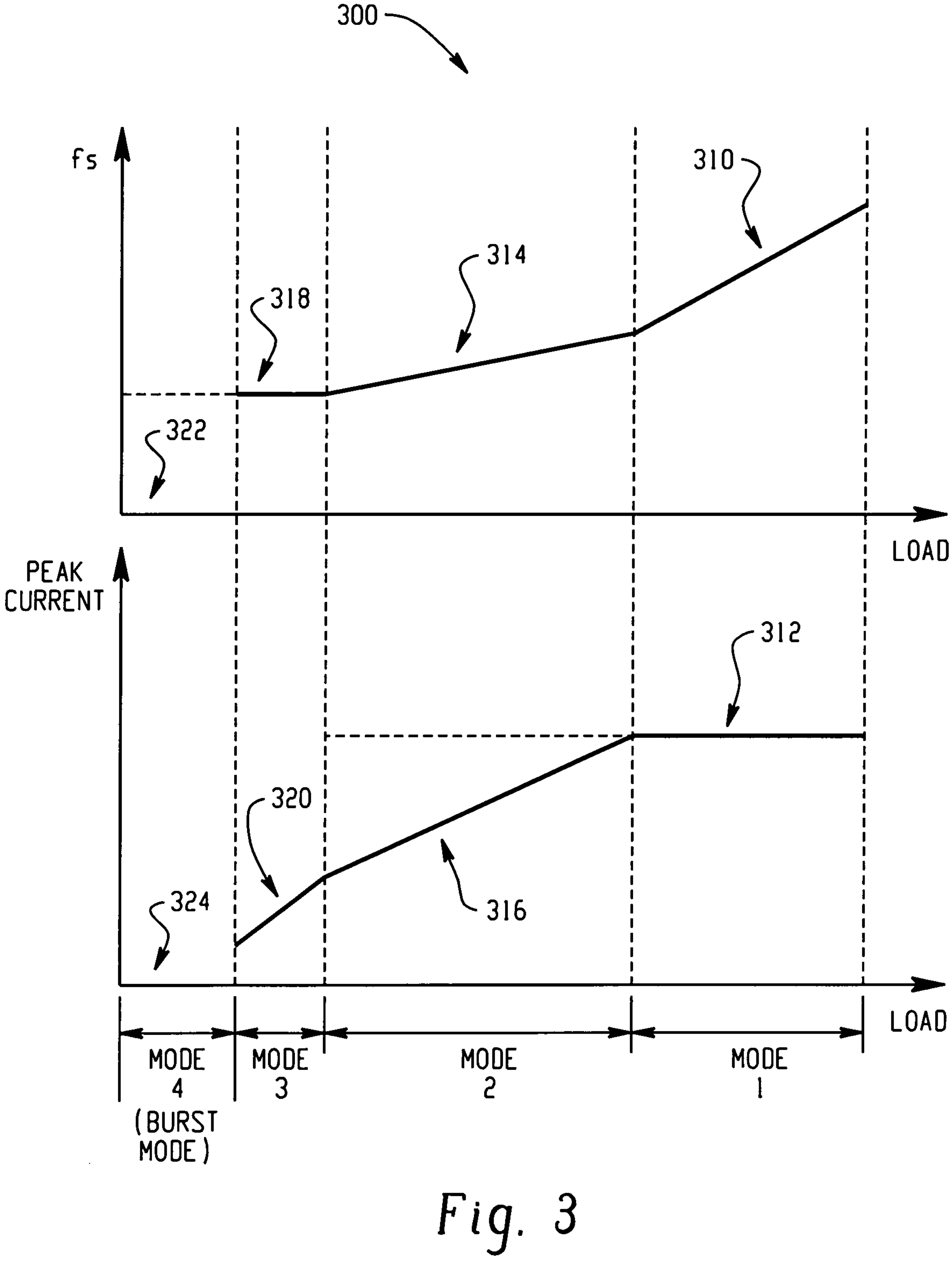
300
fs
310
314
318
322
LOAD
PEAK CURRENT
312
320
324
316
LOAD
MODE 4 (BURST MODE)
MODE 3
MODE 2
MODE 1

Fig. 3

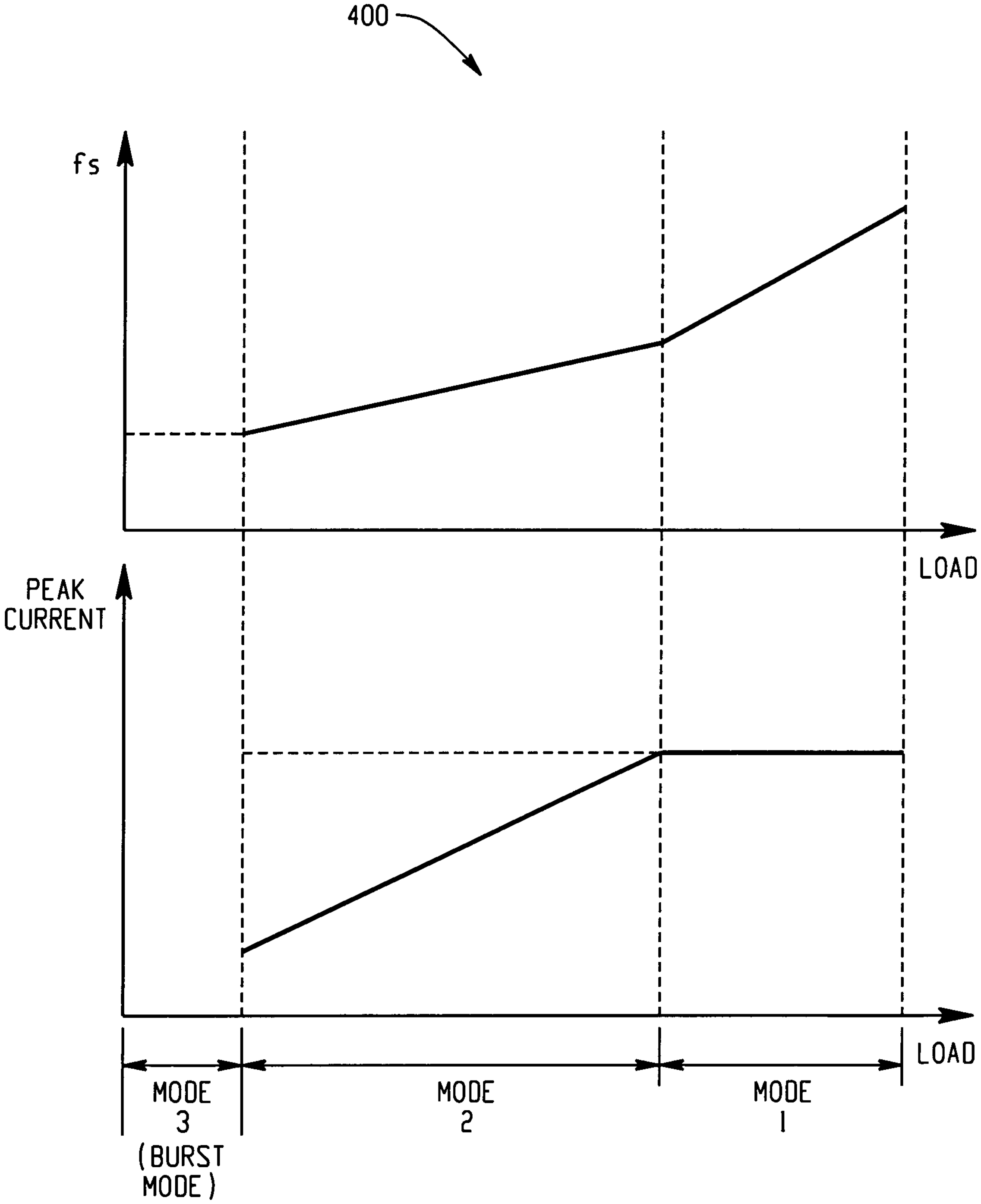

Fig. 4

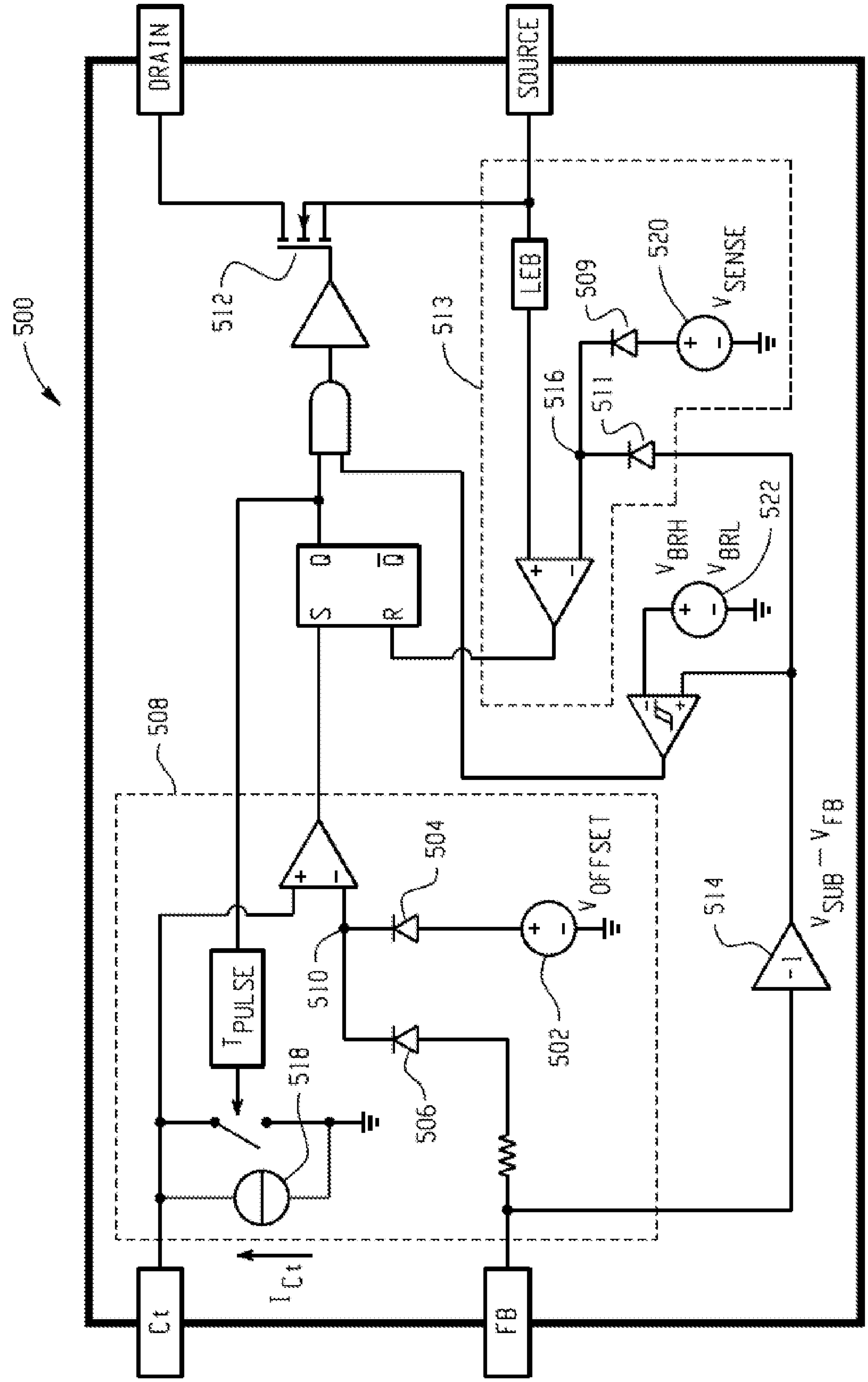
500
DRAIN
SOURCE
512
513
LEB
509
520
V SENSE
516
511
522
V BRH
V BRL
S
R
Q
Q̄
508
504
V OFFSET
510
502
506
518
T PULSE
I Ct
Ct
FB
514
-1
V SUB − V FB

Fig. 5

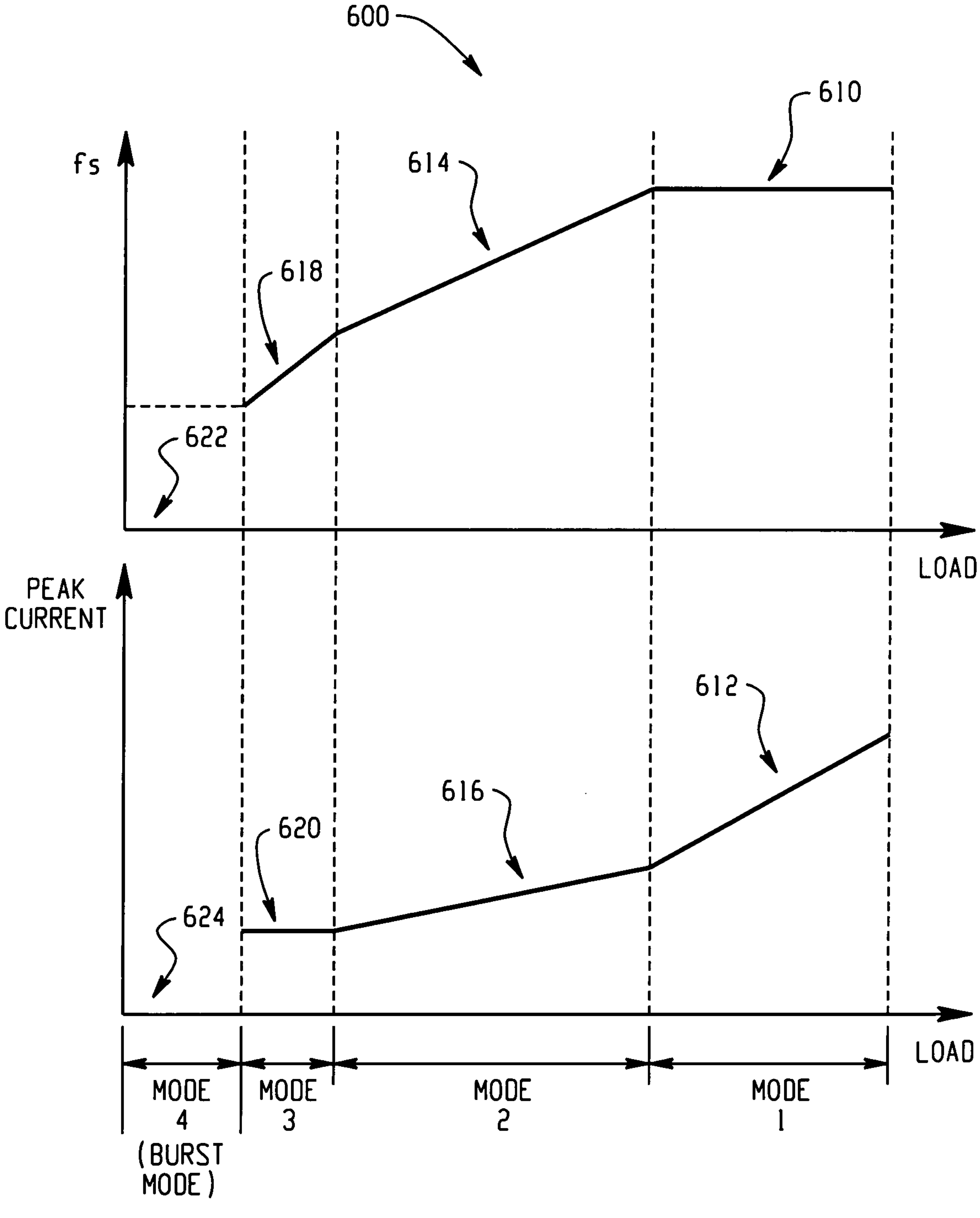
600
610
fs
614
618
622
LOAD
PEAK CURRENT
612
616
620
624
LOAD
MODE 4 (BURST MODE)
MODE 3
MODE 2
MODE 1

Fig. 6

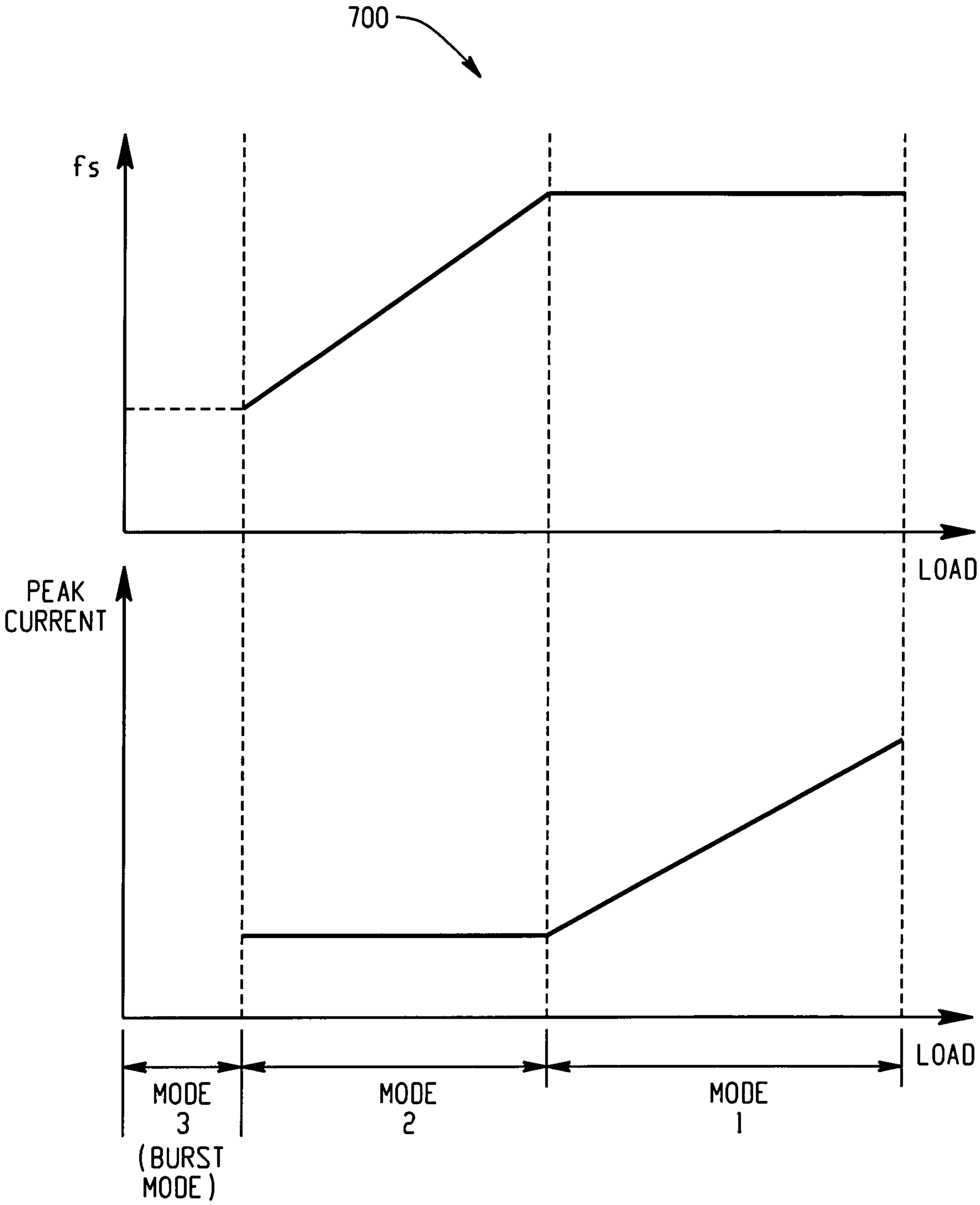

Fig. 7

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 5991172 A **[0003]**
- US 20050046399 A **[0004]**
- US 7433211 B **[0005]**
- US 5390101 A **[0006]**