US009893615B2

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

(10) **Patent No.: US 9,893,615 B2**
(45) **Date of Patent: Feb. 13, 2018**

(54) **SWITCHING POWER SUPPLY**

(71) Applicant: **YAZAKI CORPORATION**, Tokyo (JP)

(72) Inventors: **Shingo Suzuki**, Shizuoka (JP); **Michito Enomoto**, Shizuoka (JP)

(73) Assignee: **YAZAKI CORPORATION**, Minato-ku, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 38 days.

(21) Appl. No.: **15/191,815**

(22) Filed: **Jun. 24, 2016**

(65) **Prior Publication Data**

US 2016/0308437 A1 Oct. 20, 2016

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2014/080219, filed on Nov. 14, 2014.

(30) **Foreign Application Priority Data**

Jan. 24, 2014 (JP) 2014-011187

(51) **Int. Cl.**
H02J 3/12 (2006.01)
G05F 1/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H02M 3/156*** (2013.01); ***H02M 1/08*** (2013.01); ***H02M 1/36*** (2013.01); *H02M 2001/0025* (2013.01)

(58) **Field of Classification Search**
CPC G05F 1/565; G05F 1/575
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0116692 A1 6/2005 Sugiyama
2007/0182396 A1 8/2007 Inatomi
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2002-112573 A 4/2002
JP 2005-168169 A 6/2005
(Continued)

OTHER PUBLICATIONS

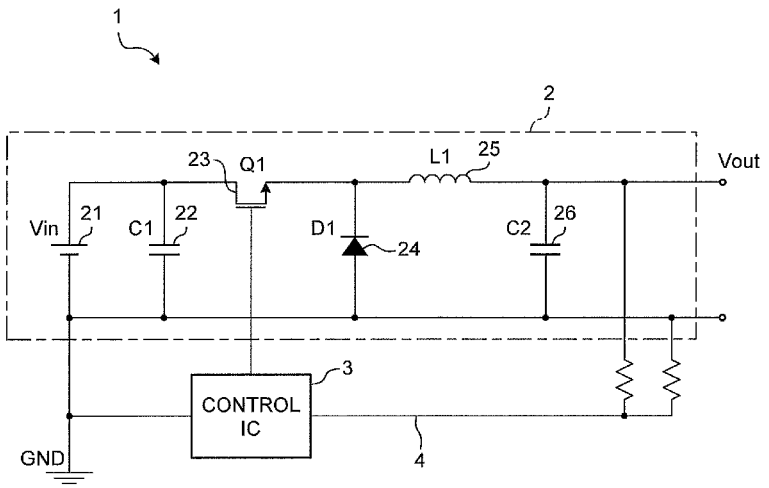
International Search Report of PCT/JP2014/080219 dated Jan. 27, 2015.

Primary Examiner — Gary Nash
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

A switching power supply includes: a switching type power supply circuit that converts an input voltage to generate an output voltage; and a control IC that executes feedback control that, based on a differential voltage between a target voltage and the output voltage from the power supply circuit, controls a switching element of the power supply circuit and causes the output voltage from the power supply circuit to converge to the target voltage. The control IC sets the target voltage for each predetermined period based on a value obtained by adding a preset value to the output voltage at a time of startup of the power supply circuit. Provided with this operation is a switching power supply that can precisely reduce an overshoot of the output voltage at the time of startup.

6 Claims, 4 Drawing Sheets



(51) **Int. Cl.**

H02M 3/156	(2006.01)
H02M 1/36	(2007.01)
H02M 1/08	(2006.01)
H02M 1/00	(2006.01)

(58) **Field of Classification Search**
USPC 323/241, 274, 282–284, 901
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0167267	A1*	7/2009	Dwarakanath	H02M 1/36 323/282
2010/0026262	A1*	2/2010	Sase	H02M 3/156 323/283
2011/0260703	A1*	10/2011	Laur	H02M 3/1563 323/271
2011/0291626	A1*	12/2011	Murakami	H02M 3/156 323/271
2012/0091978	A1	4/2012	Ishii	
2014/0049994	A1	2/2014	Ishii	

FOREIGN PATENT DOCUMENTS

JP	2007-215268	A	8/2007
JP	2008-301581	A	12/2008
JP	2012-60819	A	3/2012
JP	2012-90387	A	5/2012

* cited by examiner

FIG.1

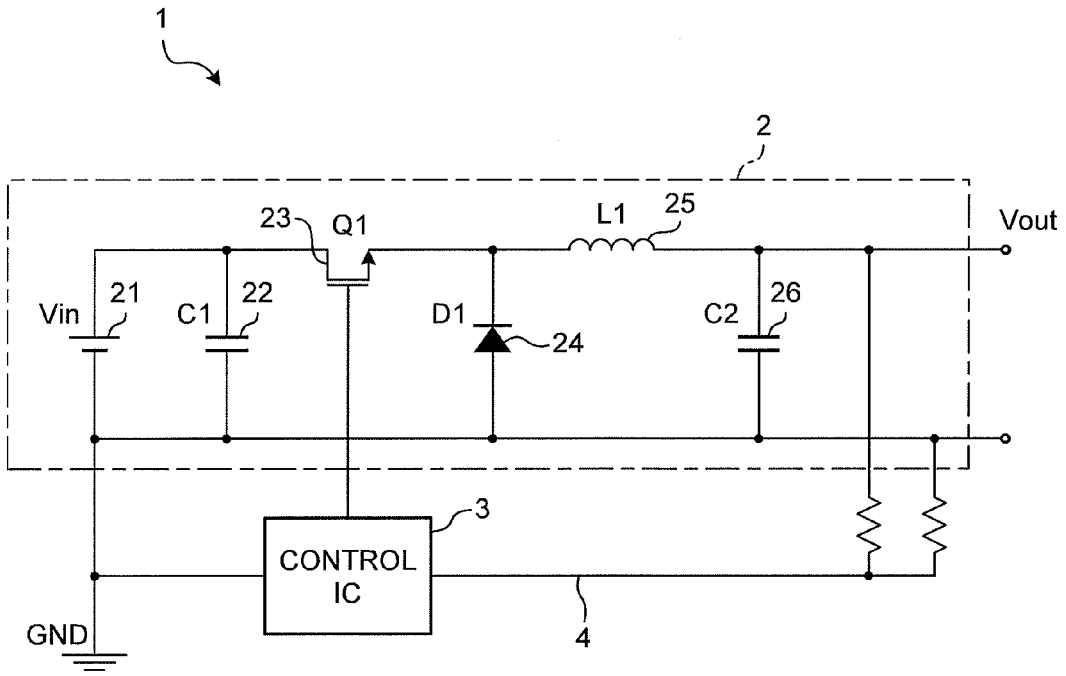

1
2
23
Q1
L1
25
Vout
Vin
21
C1
22
D1
24
C2
26
3
CONTROL IC
GND
4

FIG.2

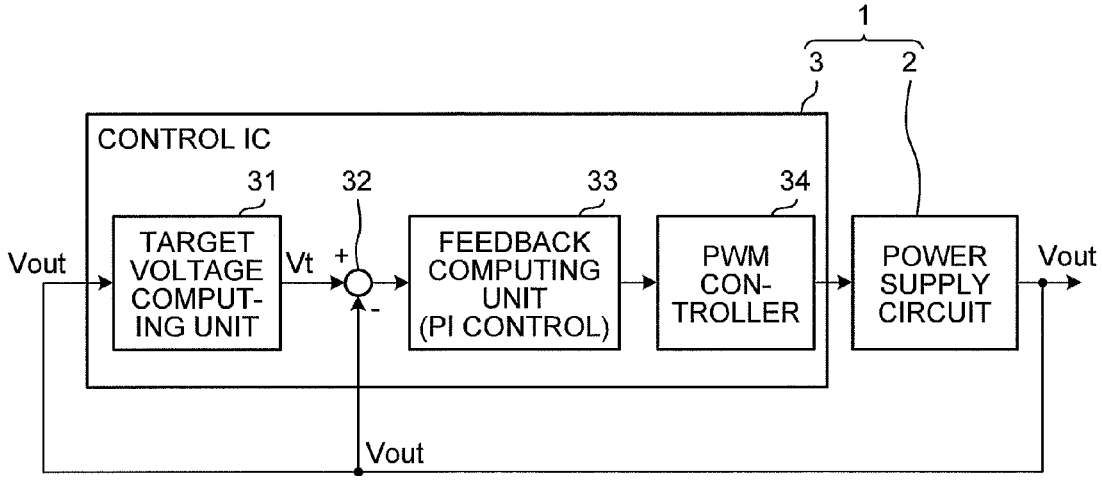

1
3
2
CONTROL IC
31
32
33
34
Vout
TARGET VOLTAGE COMPUT-ING UNIT
Vt
+
-
FEEDBACK COMPUTING UNIT (PI CONTROL)
PWM CON-TROLLER
POWER SUPPLY CIRCUIT
Vout
Vout

FIG.3

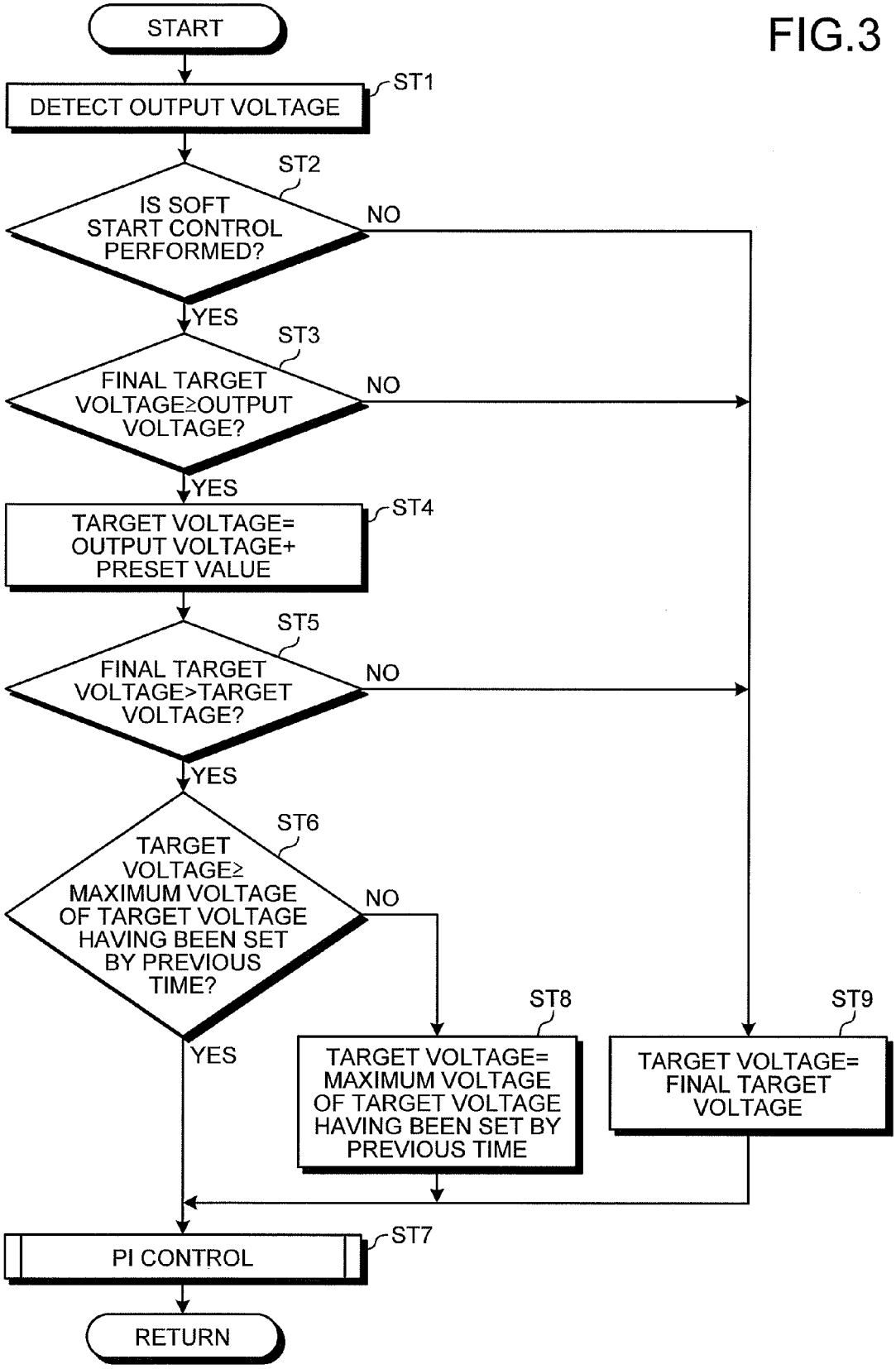

START
DETECT OUTPUT VOLTAGE
ST1
ST2
IS SOFT START CONTROL PERFORMED?
NO
YES
ST3
FINAL TARGET VOLTAGE≥OUTPUT VOLTAGE?
NO
YES
TARGET VOLTAGE= OUTPUT VOLTAGE+ PRESET VALUE
ST4
ST5
FINAL TARGET VOLTAGE>TARGET VOLTAGE?
NO
YES
ST6
TARGET VOLTAGE≥ MAXIMUM VOLTAGE OF TARGET VOLTAGE HAVING BEEN SET BY PREVIOUS TIME?
NO
YES
ST8
TARGET VOLTAGE= MAXIMUM VOLTAGE OF TARGET VOLTAGE HAVING BEEN SET BY PREVIOUS TIME
ST9
TARGET VOLTAGE= FINAL TARGET VOLTAGE
PI CONTROL
ST7
RETURN

FIG.4

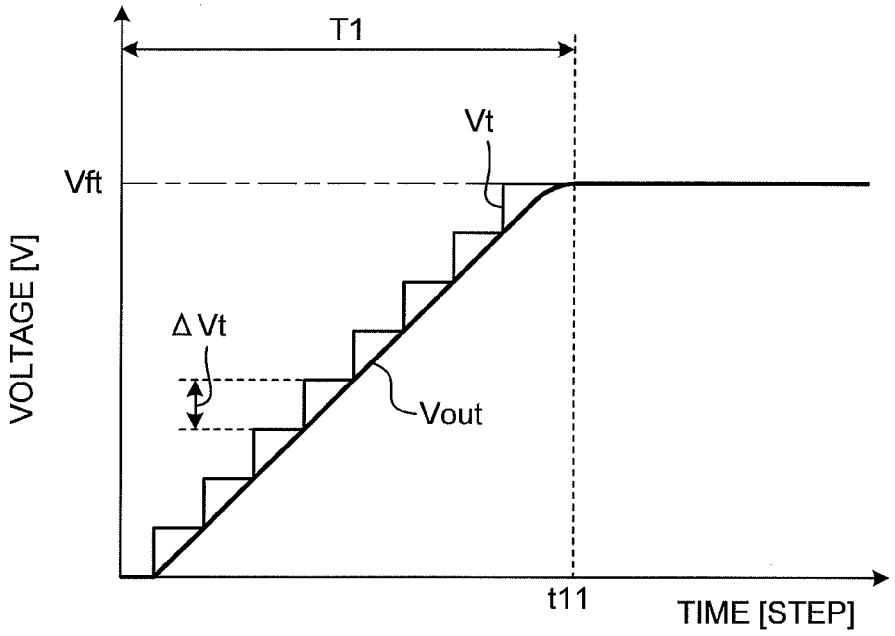

T1
Vt
Vft
VOLTAGE [V]
ΔVt
Vout
t11
TIME [STEP]

FIG.5

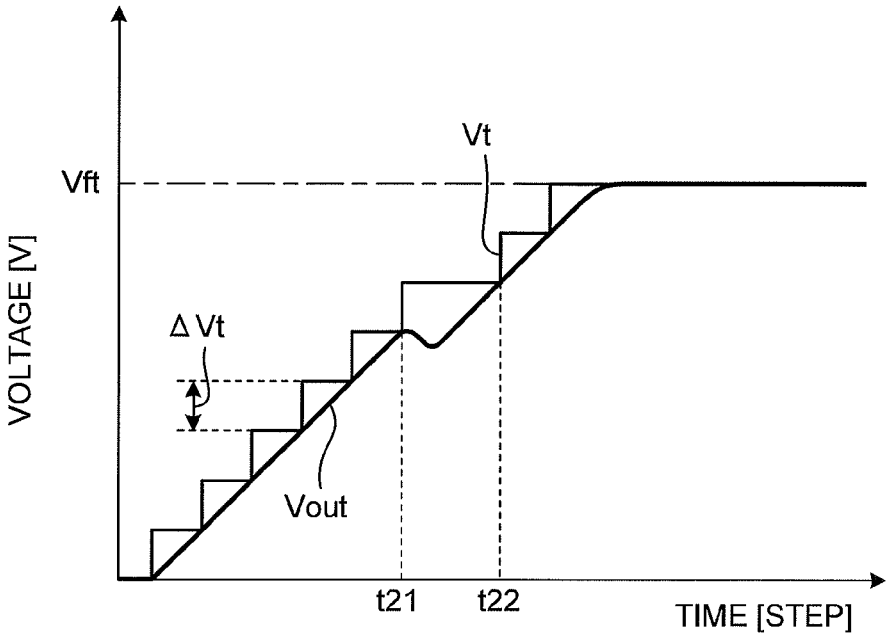
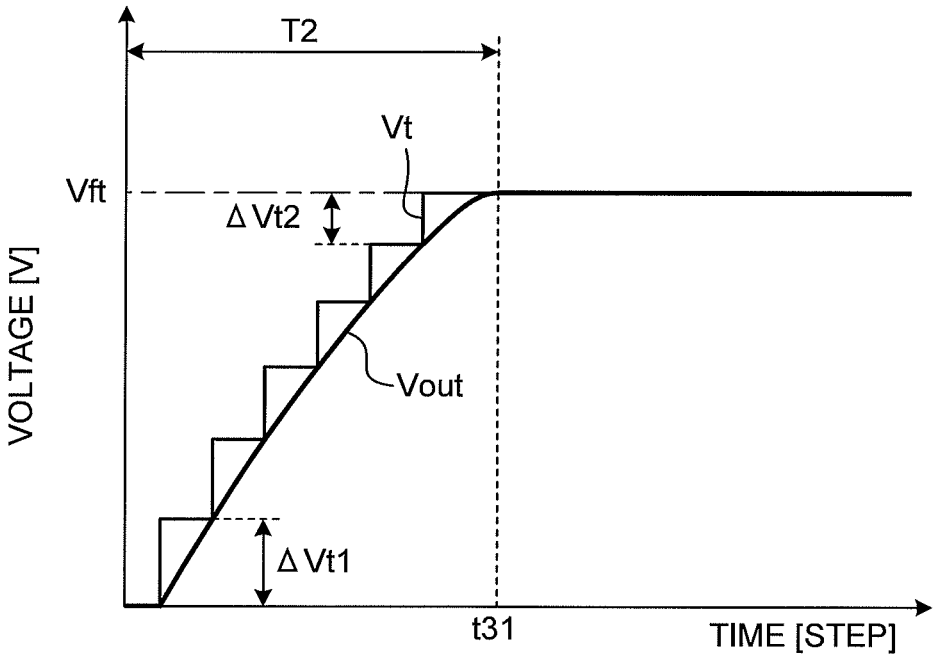

Vt
Vft
VOLTAGE [V]
ΔVt
Vout
t21
t22
TIME [STEP]

FIG.6



SWITCHING POWER SUPPLY

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation application of International Application PCT/JP2014/080219, filed on Nov. 14, 2014, and designating the U.S., the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a switching power supply.

2. Description of the Related Art

Japanese Patent Application Laid-open No. 2008-301581 discloses a switching type DC-DC converter having a soft-start circuit as a conventional switching power supply, for example. This soft-start circuit, until an output voltage of the converter reaches a set voltage, compares a voltage by a capacitor for soft start and a dividing resistor for soft start with a reference voltage that is equal to a voltage by a dividing resistor for output voltage detection when the output voltage is the set voltage, and controls a duty period of an output transistor.

Although the switching type DC-DC converter having the soft-start circuit reduces an overshoot of the output voltage at startup by being configured as described above, a more precise overshoot reduction is demanded, for example.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above circumstances, and an object thereof is to provide a switching power supply that can precisely reduce an overshoot of an output voltage at startup.

In order to achieve the above mentioned object, a switching power supply according to one aspect of the present invention includes a switching type power supply circuit configured to convert an input voltage to generate an output voltage; and a control integrated circuit configured to execute feedback control that, based on a differential voltage between a target voltage and the output voltage from the power supply circuit, controls a switching element of the power supply circuit and causes the output voltage from the power supply circuit to converge to the target voltage, wherein the control integrated circuit sets the target voltage for each predetermined period based on a value obtained by adding a preset value to the output voltage at a time of startup of the power supply circuit.

According to another aspect of the present invention, in the switching power supply, it is possible to configure that when a value obtained by adding the preset value to the output voltage is lower than a maximum voltage of the target voltage in the past set during this-time startup at the time of startup of the power supply circuit, the control integrated circuit sets the maximum voltage as the target voltage.

According to still another aspect of the present invention, in the switching power supply, it is possible to configure that the control integrated circuit makes the preset value variable.

According to still another aspect of the present invention, in the switching power supply, it is possible to configure that the control integrated circuit makes the preset value relatively larger when a differential voltage between a predetermined final target voltage and the output voltage is relatively larger, and makes the preset value relatively smaller when the differential voltage between the final target voltage and the output voltage is relatively smaller.

According to still another aspect of the present invention, in the switching power supply, it is possible to configure that the control integrated circuit fixes the target voltage to the final target voltage after the target voltage or the output voltage becomes a predetermined final target voltage.

The above and other objects, features, advantages and technical and industrial significance of this invention will be better understood by reading the following detailed description of presently preferred embodiments of the invention, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a configuration diagram illustrating a schematic configuration of a switching power supply according to an embodiment;

FIG. **2** is a block diagram illustrating an example of a schematic configuration of a control IC of the switching power supply according to the embodiment;

FIG. **3** is a flowchart illustrating an example of startup control by the control IC of the switching power supply according to the embodiment;

FIG. **4** is a diagram illustrating an example of an output voltage waveform when the startup control by the control IC of the switching power supply according to the embodiment is performed;

FIG. **5** is a diagram illustrating an example of an output voltage waveform when the startup control by the control IC of the switching power supply according to the embodiment is performed; and

FIG. **6** is a diagram illustrating an example of an output voltage waveform when startup control by a control IC of a switching power supply according to a modification is performed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following describes an embodiment according to the present invention in detail with reference to the accompanying drawings. The present invention is not limited by this embodiment. Components in the following embodiment include components that can easily be replaced by those skilled in the art or substantially the same components.

Embodiment

FIG. **1** is a configuration diagram illustrating a schematic configuration of a switching power supply according to the embodiment. FIG. **2** is a block diagram illustrating an example of a schematic configuration of a control IC of the switching power supply according to the embodiment. FIG. **3** is a flowchart illustrating an example of startup control by the control IC of the switching power supply according to the embodiment. FIG. **4** and FIG. **5** are diagrams illustrating an example of an output voltage waveform when the startup control by the control IC of the switching power supply according to the embodiment is performed.

The switching power supply **1** according to the embodiment illustrated in FIG. **1** includes a switching type power supply circuit **2** that converts an input voltage Vin to generate an output voltage Vout, and a control integrated circuit (IC) **3** that controls a switching element (a transistor **23**) of the power supply circuit **2**. This switching power

supply **1** performs on/off control of the switching element of the power supply circuit **2** by the control IC **3**, thereby generating and outputting a stable direct-current voltage from the power supply circuit **2**.

The power supply circuit **2** of the present embodiment is a switching type step-down DC-DC converter circuit including a power supply **21**, a capacitor (C**1**) **22**, the transistor (Q**1**) **23** as the switching element, a diode (D**1**) **24**, an inductor (L**1**) **25**, and a capacitor (C**2**) **26**. The power supply **21** is a direct-current power supply, in which a GND terminal is connected to a negative pole, and one end of the capacitor **22** and a drain terminal of the transistor **23** are connected to a positive pole. The capacitor **22** is a smoothing capacitor, in which the GND terminal is connected to the other end. The transistor **23** is an N-channel field effect transistor (FET), in which the positive pole of the power supply **21** is connected to the drain terminal as described above, a cathode of the diode **24** and one end of the inductor **25** are connected to a source terminal, and the control IC **3** is connected to a gate terminal. The diode **24** is a rectifying diode, in which the GND terminal is connected to an anode. To the other end of the inductor **25**, one end of the capacitor **26** and an output terminal (an output terminal of the power supply circuit **2**) to a load device (an electric instrument consuming electric power) are connected. The capacitor **26** is a smoothing capacitor, in which the GND terminal is connected to the other end. The control IC **3** controls a duty period (an on period) of the transistor **23**, whereby the power supply circuit **2** performs voltage conversion of the direct-current input voltage Vin applied by the power supply **21** into the direct-current output voltage Vout and outputs the output voltage Vout to the load device from the output terminal.

The control IC **3** controls a drive of the power supply circuit **2** and is an integrated circuit including an electronic circuit mainly including a well-known microcomputer including a CPU, a ROM, a RAM, and an interface. To the control IC **3**, the GND terminal and the gate terminal of the transistor **23** are connected, the output terminal of the power supply circuit **2** is connected via a voltage detection line **4**, and the output voltage Vout from the power supply circuit **2** is input. The control IC **3** performs feedback control that, based on a differential voltage between a target voltage Vt and the output voltage Vout from the power supply circuit **2**, controls the transistor **23** as the switching element of the power supply circuit **2** and causes the output voltage Vout from the power supply circuit **2** to converge to the target voltage Vt. The control IC **3** computes a controlled variable of the transistor **23** based on the differential voltage between the target voltage Vt and the output voltage Vout and controls the transistor **23** based on the controlled variable.

More specifically, the control IC **3** computes the differential voltage between the target voltage Vt and the output voltage Vout from the power supply circuit **2** input via the voltage detection line **4**. The target voltage Vt is a voltage as a target of the output voltage Vout in the feedback control, which is typically determined in accordance with a voltage required by the load device connected to the power supply circuit **2** or the like and is variably set at the startup of the power supply circuit **2** as described below. The control IC **3** computes the controlled variable of the transistor **23** based on the computed differential voltage between the target voltage Vt and the output voltage Vout. The controlled variable of the transistor **23** is typically a duty period corresponding to the length of the on period of the transistor **23** as the switching element. The output voltage Vout of the power supply circuit **2** becomes relatively larger as the duty period becomes relatively longer and becomes relatively smaller as the duty period becomes relatively shorter. The control IC **3** computes the duty period as the controlled variable of the transistor **23** so that the computed differential voltage between the target voltage Vt and the output voltage Vout will be smaller (that is, so that the output voltage Vout will converge to the target voltage Vt) by what is called P control, PI control, or PID control. The control IC **3** stores a controlled variable map (or a mathematical model) and the like that specifies a correspondence relation between the differential voltage between the target voltage Vt and the output voltage Vout and the duty period as the controlled variable of the transistor **23** in a storage unit and computes the duty period as a target of control from the differential voltage between the target voltage Vt and the output voltage Vout using the controlled variable map, for example. Specifically, the control IC **3** makes the duty period relatively longer as the differential voltage between the target voltage Vt and the output voltage Vout becomes relatively larger and makes the duty period relatively shorter as the differential voltage becomes relatively smaller. Based on the computed duty period, the control IC **3** generates a pulse-width-modulated PWM signal (a pulse signal) and outputs the PWM signal to the transistor **23** and performs on/off control of the transistor **23** so that the output voltage Vout will converge to the target voltage Vt.

The control IC **3** of the present embodiment performs setting so as to increase the target voltage Vt in stages at a time of startup of the power supply circuit **2** and can thereby precisely reduce an overshoot of the output voltage Vout at the startup of the power supply circuit **2**.

At the time of startup of the power supply circuit **2** is typically a period from a point in time when a startup signal of the power supply circuit **2** is input to the switching power supply **1** or a preset startup condition is satisfied, whereby the startup of the power supply circuit **2** is started, to a point in time when the output voltage Vout of the power supply circuit **2** converges to a predetermined final target voltage Vft. The final target voltage Vft is set as a fixed value in advance in accordance with the voltage required by the load device connected to the power supply circuit **2** and is stored in the storage unit.

Specifically, the control IC **3** sets the target voltage Vt based on a value obtained by adding a preset value ΔVt to the output voltage Vout at the time of startup of the power supply circuit **2**. The preset value ΔVt is a value freely set in advance. The overshoot of the output voltage Vout at startup tends to occur when the duty period corresponding to the length of the on period of the transistor **23** is relatively longer. In consideration of this point, the preset value ΔVt is set in advance based on an experiment or the like as a value that does not cause the overshoot owing to an excessively long duty period and is stored in the storage unit. In this example, the preset value ΔVt is a fixed value.

When the value obtained by adding the preset value ΔVt to the output voltage Vout is lower than a maximum voltage Vtmax of the target voltage Vt in the past having been set during this-time startup, at the startup of the power supply circuit **2**, the control IC **3** of the present embodiment sets the maximum voltage Vtmax as the target voltage Vt. With this operation, the control IC **3** causes the temporarily set target voltage Vt not to decrease at the startup of the power supply circuit **2**. The control IC **3** of the present embodiment fixes the target voltage Vt to the final target voltage Vft after the target voltage Vt or the output voltage Vout reaches the final target voltage Vft. In other words, the control IC **3** sets the target voltage Vt to the value obtained by adding the preset

value ΔVt to the output voltage Vout when the output voltage Vout is the final target voltage Vft or less and when the value obtained by adding the preset value ΔVt to the output voltage Vout is less than the final target voltage Vft at the startup of the power supply circuit **2**.

The following describes an example of a schematic configuration of the control IC **3** of the present embodiment with reference to the block diagram in FIG. **2**.

As illustrated in FIG. **2**, the control IC **3** is configured to include a target voltage computing unit **31**, a subtracting unit **32**, a feedback computing unit **33**, and a PWM controller **34** in terms of functional concepts.

The target voltage computing unit **31** computes the target voltage Vt. To the target voltage computing unit **31**, the output voltage Vout from the power supply circuit **2** is input via the voltage detection line **4**. The target voltage computing unit **31** detects the output voltage Vout at the start of the startup (immediately before the start of the startup) of the power supply circuit **2** and checks the state of the output voltage Vout. The output voltage Vout at the start of the startup (immediately before the start of the startup) of the power supply circuit **2** is not limited to 0 V and may be a certain voltage under the influence of a load state of the load device connected to the power supply circuit **2**, for example. However, the output voltage Vout at the start of the startup (immediately before the start of the startup) of the power supply circuit **2** is typically less than the final target voltage Vft. The target voltage computing unit **31** sets the target voltage Vt based on the value obtained by adding the preset value ΔVt to the output voltage Vout at the startup of the power supply circuit **2**. When the value obtained by adding the preset value ΔVt to the output voltage Vout is lower than a maximum voltage Vtmax of the target voltage Vt in the past having been set during this-time startup, at the startup of the power supply circuit **2**, the target voltage computing unit **31** sets the maximum voltage Vtmax as the target voltage Vt. After the target voltage Vt or the output voltage Vout reaches the final target voltage Vft, the target voltage computing unit **31** fixes the target voltage Vt to the final target voltage Vft. The target voltage computing unit **31** outputs the target voltage Vt that has been computed and set to the subtracting unit **32**.

The subtracting unit **32** computes the differential voltage between the target voltage Vt and the output voltage Vout. To the subtracting unit **32**, the target voltage Vt is input from the target voltage computing unit **31**, and the output voltage Vout from the power supply circuit **2** is input via the voltage detection line **4**. The subtracting unit **32** computes the differential voltage between the input target voltage Vt and output voltage Vout and outputs the computed differential voltage to the feedback computing unit **33**.

The feedback computing unit **33** computes the controlled variable (a feedback controlled variable) of the transistor **23** based on the differential voltage between the target voltage Vt and the output voltage Vout. To the feedback computing unit **33**, the differential voltage between the target voltage Vt and the output voltage Vout is input from the subtracting unit **32**. The feedback computing unit **33** computes the duty period as the controlled variable of the transistor **23** so that, based on the differential voltage between the input target voltage Vt and output voltage Vout, the differential voltage will be smaller by P control, PI control, or PID control (PI control as an example in this example). The feedback computing unit **33** outputs a signal corresponding to the computed duty period to the PWM controller **34**.

The PWM controller **34** actually performs on/off control of the transistor **23** in accordance with the duty period as the controlled variable of the transistor **23**. To the PWM controller **34**, the signal corresponding to the duty period as the controlled variable of the transistor **23** is input from the feedback computing unit **33**. The PWM controller **34** generates a PWM signal pulse-width-modulated based on the input signal corresponding to the duty period, outputs the PWM signal to the transistor **23**, and performs on/off control of the transistor **23** so that the output voltage Vout will converge to the target voltage Vt.

Next, the following describes an example of startup control of the power supply circuit **2** by the control IC **3** with reference to the flowchart in FIG. **3**. These control routines are repeatedly executed at a control period (in units of clocks) of a few milliseconds to a few tens of milliseconds.

First, when the startup signal of the power supply circuit **2** is input or the preset startup condition is satisfied, whereby the startup of the power supply circuit **2** is started, the target voltage computing unit **31** of the control IC **3** detects the present output voltage Vout (Step ST**1**).

Next, the target voltage computing unit **31** determines whether soft start control, that is, control to perform setting so as to increase the target voltage Vt in stages is to be performed at the startup of the power supply circuit **2** (Step ST**2**). The target voltage computing unit **31** may determine the necessity of the soft start control in accordance with an operating state of the entire switching power supply **1**, the load state of the load device connected to the power supply circuit **2**, or the like, for example; it is basically determined that the soft start control is necessary in this example.

If it is determined that the soft start control is performed (Yes at Step ST**2**), the target voltage computing unit **31** determines whether the present output voltage Vout is the predetermined final target voltage Vft or less (Step ST**3**).

If it is determined that the present output voltage Vout is the final target voltage Vft or less (Yes at Step ST**3**), the target voltage computing unit **31** computes a value obtained by adding the predetermined preset value ΔVt to the present output voltage Vout and temporarily sets this value as the target voltage Vt (Step ST**4**).

Next, the target voltage computing unit **31** determines whether the target voltage Vt computed at Step ST**4** is less than the final target voltage Vft (Step ST**5**).

If it is determined that the target voltage Vt computed at Step ST**4** is less than the final target voltage Vft (Yes at Step ST**5**), the target voltage computing unit **31** determines whether the target voltage Vt computed at Step ST**4** is the maximum voltage Vtmax of the target voltage Vt having been set by the previous control period or more (Step ST**6**). In other words, with this operation, the target voltage computing unit **31** determines whether the target voltage Vt of the present control period obtained by adding the preset value ΔVt to the output voltage Vout is the maximum voltage Vtmax of target voltage Vt in the past having been set during this-time startup or more at the startup of the power supply circuit **2**.

If it is determined by the target voltage computing unit **31** that the target voltage Vt computed at Step ST**4** is the maximum voltage Vtmax of the target voltage Vt having been set by the previous control period or more (Yes at Step ST**6**), the control IC **3** executes PI control of the transistor **23** based on the value obtained by adding the preset value ΔVt to the presently set target voltage Vt, or the present output voltage Vout in this example (Step ST**7**), ends the present control period, and shifts to the next control period. In this case, the subtracting unit **32** of the control IC **3** computes a differential voltage between the presently set target voltage Vt and the output voltage Vout. The feedback

computing unit **33** of the control IC **3** computes the duty period as the controlled variable of the transistor **23** based on the differential voltage. The PWM controller **34** of the control IC **3** outputs the PWM signal pulse-width-modulated based on the duty period to the transistor **23** and performs on/off control of the transistor **23**.

If it is determined that the target voltage Vt computed at Step ST**4** is smaller than the maximum voltage Vtmax of the target voltage Vt having been set by the previous control period at Step ST**6** (No at Step ST**6**), the target voltage computing unit **31** sets the maximum voltage Vtmax as the target voltage Vt (Step ST**8**) and performs the processing at Step ST**7**. In this case, the control IC **3** executes PI control of the transistor **23** based on the presently set target voltage Vt, or the maximum voltage Vtmax of the target voltage Vt having been set by the previous control period in this example.

If it is determined that the soft start control is not to be performed at Step ST**2** (No at Step ST**2**), if it is determined that the present output voltage Vout is larger than the final target voltage Vft at Step ST**3** (No at Step ST**3**), or if it is determined that the target voltage Vt computed at Step ST**4** is the final target voltage Vft or more at Step ST**5** (No at Step ST**5**), the target voltage computing unit **31** fixes the target voltage Vt to the final target voltage Vft (Step ST**9**) and performs the processing at Step ST**7**. In this case, the control IC **3** executes PI control of the transistor **23** based on the presently set target voltage Vt, or the final target voltage Vft in this example.

FIG. **4** and FIG. **5** illustrate an example of an output voltage waveform when the above startup control is performed by the control IC **3**. In FIG. **4** and FIG. **5**, the horizontal axis is a time axis by the control period (Time [STEP]), and the vertical axis is a voltage (Voltage [V]).

As illustrated in FIG. **4**, the switching power supply **1** configured as described above is set so that the target voltage Vt will increase in stages by each control period by the control IC **3** at the startup of the power supply circuit **2**. In the switching power supply **1** of the present embodiment, the value obtained by adding the preset value ΔVt to the present output voltage Vout is set as the target voltage Vt by the control IC **3** at the startup of the power supply circuit **2**. With this operation, the switching power supply **1** can prevent the differential voltage between the target voltage Vt and the output voltage Vout from being extremely large at the startup of the power supply circuit **2**. In this example, the switching power supply **1** can gradually increase the target voltage Vt based on the present output voltage Vout by setting the value obtained by adding the preset value ΔVt to the output voltage Vout as the target voltage Vt at the startup of the power supply circuit **2** and can thereby reliably prevent the differential voltage between the target voltage Vt and the output voltage Vout from being extremely large. As a result, the switching power supply **1** can relatively reduce the duty period that the transistor **23** is requested to exhibit at the startup of the power supply circuit **2**. Consequently, the switching power supply **1** can prevent a phenomenon in which the output voltage Vout is extremely large relative to the target voltage Vt, that is, the overshoot from occurring at the startup of the power supply circuit **2**. The switching power supply **1** can set a larger value than the present output voltage Vout as the target voltage Vt even at the initial stage of startup and can thereby improve rising of the target voltage Vt and the output voltage Vout and quickly start up the power supply circuit **2**. After the target voltage Vt is fixed to the final target voltage Vft, the output voltage Vout converges to the target voltage Vt at a point in time t**11**, and the startup of the power supply circuit **2** completes, whereby the switching power supply **1** can output a stable output voltage Vout. In the example in FIG. **4**, a startup period T**1** of the power supply circuit **2** is the period from the point in time when the startup of the power supply circuit **2** is started to the point in time t**11** when the output voltage Vout of the power supply circuit **2** converges to the target voltage Vt (=the final target voltage Vft).

In the switching power supply **1**, when the value obtained by adding the preset value ΔVt to the output voltage Vout is lower than the maximum voltage Vtmax of the target voltage Vt in the past having been set during this-time startup, at the startup of the power supply circuit **2**, the maximum voltage Vtmax is set as the target voltage Vt by the control IC **3**. Consequently, even when the output voltage Vout temporarily decreases owing to a sudden rise of the load of the load device connected to the power supply circuit **2** or the like, for example, as illustrated in from a point in time t**21** to a point in time t**22** in FIG. **5**, the switching power supply **1** can cause the temporarily set target voltage Vt not to decrease.

The switching power supply **1** of the present embodiment controls the duty period that the transistor **23** is requested to exhibit by the computation in the control IC **3** to perform startup control of the power supply circuit **2** as described above and can thereby reduce the influence of parts characteristic variations compared with a case in which similar functionality is achieved by an analog circuit, for example, whereby the overshoot of the output voltage Vout at the startup of the power supply circuit **2** can precisely be reduced. The switching power supply **1** can reduce the number of components compared with a case in which similar functionality is achieved by an analog circuit, for example, and can thereby reduce a component mounting area and miniaturize the device. Furthermore, the switching power supply **1** can achieve a function of soft start control (startup control) by the computation in the control IC **3** without using parts such as capacitors and resistors and can thereby practically prevent deterioration of parts related to the function of the soft start control and can be operated constantly with a similar level of accuracy. In other words, the switching power supply **1** can prevent the influence of changes in parts characteristics caused by deterioration over time and can thereby precisely reduce the overshoot even when being used for a long term. Even when specifications required for the switching power supply **1** are changed, the switching power supply **1** can adapt to the required specifications by altering the control IC **3** in terms of software without altering parts, thereby making design alterations easy.

The switching power supply **1** described above includes the switching type power supply circuit **2** that converts the input voltage Vin to generate the output voltage Vout and the control IC **3** that executes feedback control that, based on the differential voltage between the target voltage Vt and the output voltage Vout from the power supply circuit **2**, controls the transistor **23** of the power supply circuit **2** and causes the output voltage Vout from the power supply circuit **2** to converge to the target voltage Vt. The control IC **3** sets the target voltage Vt based on the value obtained by adding the preset value ΔVt to the output voltage Vout at the startup of the power supply circuit **2**. Consequently, the switching power supply **1** performs startup control of the power supply circuit **2** by the computation in the control IC **3**, whereby the influence of parts characteristic variations can be reduced, and the overshoot of the output voltage Vout can precisely

be reduced at the startup of the power supply circuit **2**. Consequently, the switching power supply **1** can improve reliability.

Furthermore, in the switching power supply **1** described above, when the value obtained by adding the preset value ΔVt to the output voltage Vout is lower than the maximum voltage Vtmax of the target voltage Vt in the past having been set during this-time startup, at the startup of the power supply circuit **2**, the control IC **3** sets the maximum voltage Vtmax as the target voltage Vt. Consequently, even when the output voltage Vout temporarily decreases, for example, the switching power supply **1** can cause the temporarily set target voltage Vt not to decrease and can thereby prevent the influence of a sudden drop of the output voltage Vout or the like and smoothly complete startup even when startup is performed with the target voltage Vt being set in accordance with the output voltage Vout.

Furthermore, in the switching power supply **1** described above, after the target voltage Vt or the output voltage Vout reaches the predetermined final target voltage Vft, the control IC **3** fixes the target voltage Vt to the final target voltage Vft. Consequently, the switching power supply **1** can output a stable output voltage Vout after the output voltage Vout converges to the target voltage Vt (the final target voltage Vft). Even when, in relation to the final target voltage Vft, the preset value ΔVt is not set to magnitude that makes the target voltage Vt specified by the sum of the output voltage Vout and the preset value ΔVt exactly match the final target voltage Vft, and the target voltage Vt specified by the sum of the output voltage Vout and the preset value ΔVt exceeds the final target voltage Vft, for example, the switching power supply **1** can fix the target voltage Vt to the final target voltage Vft when the target voltage Vt is about to exceed the final target voltage Vft. Also in this regard, the switching power supply **1** can reliably output a stable output voltage Vout.

The switching power supply according to the embodiment of the present invention described above is not limited to the embodiment described above, and various alterations can be made within the scope described in the claims.

Although the control IC **3** is described with the preset value ΔVt as a fixed value in the above description, the preset value ΔVt may be variable. The control IC **3** may alter the preset value ΔVt based on an external environment of the switching power supply **1**, a load condition of the load device connected to the power supply circuit **2**, or the like, for example. The control IC **3** can also freely set the startup time of the power supply circuit **2** by appropriately altering this preset value ΔVt, for example. In other words, this switching power supply **1** can easily alter the startup time of the power supply circuit **2** to a desired time by altering the preset value ΔVt in terms of software, whereby manufacturing costs can also be reduced.

FIG. **6** is a diagram illustrating an example of an output voltage waveform when startup control by a control IC of a switching power supply according to a modification is performed.

The control IC **3** of the switching power supply **1** according to the present modification computes and sets the preset value ΔVt based on a differential voltage between the final target voltage Vft and the output voltage Vout as an example. As illustrated in FIG. **6**, the target voltage computing unit **31** of the control IC **3** according to the present modification makes the preset value ΔVt relatively larger when the differential voltage between the final target voltage Vft and the output voltage Vout is relatively larger and makes the preset value ΔVt relatively smaller when the differential voltage is relatively smaller. In this example, the target voltage computing unit **31** sets a preset value ΔVt2 immediately before the completion of startup at which the differential voltage between the final target voltage Vft and the output voltage Vout is relatively smaller to a value smaller than a preset value ΔVt1 at the initial stage of startup at which the differential voltage is relatively larger. In this case, the target voltage computing unit **31** may make the preset value ΔVt in the period from the preset value ΔVt1 to the preset value ΔVt2 decrease in stages based on the differential voltage between the final target voltage Vft and the output voltage Vout.

In this case, the switching power supply **1** according to the modification can make the preset value ΔVt at the initial stage of startup (ΔVt1) relatively larger to the extent that no overshoot occurs and make the preset value ΔVt immediately before the completion of startup (ΔVt2) relatively smaller, whereby the overshoot can reliably be reduced while improving the rising of the output voltage Vout and quickly starting up the power supply circuit **2**. In the example in FIG. **6**, a startup period T**2** from the point in time when the startup of the power supply circuit **2** is started to a point in time t**31** when the output voltage Vout of the power supply circuit **2** converges to the target voltage Vt (=the final target voltage Vft) is relatively shorter than the startup period T**1** (refer to FIG. **4**).

Although described as the switching type step-down DC-DC converter circuit in the above description, the power supply circuit **2** is not limited to this example and may be a switching type step-up DC-DC converter circuit or another circuit including a switching element, for example. Although described as including the power supply **21** as a direct-current power supply, the power supply circuit **2** is not limited to this example, may include an input terminal to which the input voltage Vin is supplied from another power supply circuit in place of the power supply **21**, and may be incorporated into part of an AC-DC converter circuit, for example.

Although it is described that, when the value obtained by adding the preset value ΔVt to the output voltage Vout is lower than the maximum voltage Vtmax of the target voltage Vt in the past having been set during this-time startup, at the startup of the power supply circuit **2**, the control IC **3** sets the maximum voltage Vtmax as the target voltage Vt, this is not limiting.

Other than the preset value ΔVt, this switching power supply **1** can also alter the final target voltage Vft, the controlled variable map that specifies the correspondence relation between the differential voltage between the target voltage Vt and the output voltage Vout and the duty period as the controlled variable of the transistor **23**, a feedback gain used in P control, PI control, PID control, or the like, and change characteristics of current and voltage, for example, in terms of software and can thereby make fine adjustments easily.

The switching power supply according to the present invention performs startup control of the power supply circuit by the computation in the control IC, thereby producing the effect of reducing the influence of parts characteristic variations and precisely reducing the overshoot of the output voltage at startup, for example.

Although the invention has been described with respect to specific embodiments for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art that fairly fall within the basic teaching herein set forth.

What is claimed is:

1. A switching power supply comprising:

a switching type power supply circuit configured to convert an input voltage to generate an output voltage; and

a control integrated circuit configured to execute feedback control that, based on a differential voltage between a target voltage and the output voltage from the power supply circuit, controls a switching element of the power supply circuit and causes the output voltage from the power supply circuit to converge to the target voltage, wherein

the control integrated circuit sets the target voltage for each predetermined period based on a value obtained by adding a preset value to the output voltage at a time of startup of the power supply circuit,

wherein, when a value obtained by adding the preset value to the output voltage is lower than a maximum voltage of the target voltage in the past set during this-time startup at the time of startup of the power supply circuit, the control integrated circuit sets the maximum voltage as the target voltage.

2. The switching power supply according to claim 1, wherein

the control integrated circuit makes the preset value variable.

3. The switching power supply according to claim 2, wherein

the control integrated circuit makes the preset value relatively larger when a differential voltage between a predetermined final target voltage and the output voltage is relatively larger, and makes the preset value relatively smaller when the differential voltage between the final target voltage and the output voltage is relatively smaller.

4. The switching power supply according to claim 3, wherein

the control integrated circuit fixes the target voltage to the final target voltage after the target voltage or the output voltage becomes a predetermined final target voltage.

5. The switching power supply according to claim 2, wherein

the control integrated circuit fixes the target voltage to the final target voltage after the target voltage or the output voltage becomes a predetermined final target voltage.

6. The switching power supply according to claim 1, wherein

the control integrated circuit fixes the target voltage to the final target voltage after the target voltage or the output voltage becomes a predetermined final target voltage.

* * * * *