The voltage of back electromotive force induced at a driving winding (nb1) by the turning-off of a high-side switching element (Q2) is input to the ZT-terminal of a switching control IC (84), and thereby the OUT-terminal of the switching control IC (84) goes to a high level. This makes a low-side switching element (Q1) turn off. A constant current circuit (CC1) uses the voltage at the OUT-terminal to charge a capacitor (C1b) with a constant current. A comparator in the switching control IC (84) inverts the voltage at the OUT-terminal to a low level when the voltage at an IS-terminal exceeds the voltage at an FB-terminal. Accordingly, the on-time of the low-side switching element (Q1) is controlled according to the voltage input to the FB-terminal, and an output voltage (Vo) is made constant. One type of control IC is thus utilized in a power conversion circuit in various switching power supply devices and a whole circuit is simply configured.
SWITCHING POWER SUPPLY DEVICE

Technical Field

The present invention relates to switching power supply devices that include switching elements and switching control circuits. In particular, the present invention makes it possible to apply a general purpose current mode IC to a high performance power conversion circuit.

Background to the Invention

Fig. 1 is a circuit diagram of a switching power supply device indicated in Japanese Unexamined Patent Application Publication No. 2001-37220. In Fig. 1, a switching power supply device 1 is based on a flyback converter circuit, and a primary switching element Q1 is turned on and off in an alternating manner. When the primary switching element Q1 is on, energy is accumulated in a transformer T and when the primary switching element Q1 is off, power is supplied to a load. In addition, the switching power supply device 1 employs a so-called voltage clamp system, in which a surge voltage that is applied to the primary switching element Q1 is clamped, and this achieves a zero voltage switching operation of the primary switching element Q1 and a secondary switching element Q2.

Specifically, in the switching power supply device 1,
an FET Q1, which serves as the primary switching element, a primary winding N1 of the transformer T, and a direct current power supply E are connected in series, and a series circuit formed by an FET Q2, which serves as the secondary switching element, and a capacitor C1 is connected between the two ends of the primary winding N1 of the transformer T.

Here, a gate of the FET Q1 is connected to one end of a first drive winding N3 via a switching control IC 2. In addition, a source of the FET Q2 is connected to a drain of the FET Q1, and a gate of the FET Q2 is connected to one end of a second drive winding N4 of the transformer T via a secondary switching element control circuit (secondary control circuit) 3.

Furthermore, the gate and the source of the FET Q2 are connected between the two ends of the second drive winding N4 via the secondary control circuit 3. The secondary control circuit 3 includes a transistor Q3, a capacitor C2, a resistor R1, a capacitor C3, a resistor R2, and an inductor 4. Of these components, the capacitor C2 and the resistor R1 form a time constant circuit.

In addition, the switching power supply device 1 includes a rectifying diode Do and a smoothing capacitor C4, which are provided at a secondary side of the transformer T.
Summary of the Invention

If the switching control IC 2 as illustrated in Fig. 1 is prepared for each of the variety of applications in a power conversion circuit and a different IC is used for a different specification or a different purpose, a large variety of ICs become necessary with an increase in the number of applications. The development and the manufacture of an individual IC require considerable processes and costs. The increase in the variety also complicates the logistics and the inventory management of the ICs, which results in a problem that the unit cost of the ICs increases.

In particular, in a current resonance type power conversion circuit having a half bridge configuration that uses two switching elements or in an insulating type power conversion circuit having a power factor correction function (PFC converter), the waveform of a current that flows in the power conversion circuit does not necessarily take on such a waveform in which a current value increases monotonously in proportion to time during an on period in which the electricity runs in the switching element, which leads to an issue that a general purpose current mode IC cannot be used.

We have appreciated that it would be desirable to provide a switching power supply device of which an entire
circuit can be configured simply without providing individual switching control ICs for the respective circuit configurations in the switching power supply device.

The invention is defined by independent claim 1 to which reference should be made.

A switching power supply device embodying the present invention includes embodying a power supply voltage input unit configured to accept input of an input power supply voltage, a direct current voltage output unit configured to receive output of a direct current voltage, a transformer (T) including a primary winding (np) and a secondary winding (ns), a low side switching element (Q1) connected in series to the primary winding (np) and configured to apply a voltage at the power supply voltage input unit to the primary winding (np) upon being turned on, a switching control circuit configured to control the low side switching element (Q1), a rectifying smoothing circuit configured to rectify and smooth a voltage outputted from the secondary winding (ns) and output an output voltage (Vo) to the direct current voltage output unit, and a feedback voltage signal generating circuit configured to generate a feedback voltage signal on the basis of the output voltage (Vo).

The switching control circuit includes a drive voltage signal output unit configured to output, upon detecting an inversion of a voltage polarity in the transformer (T), a
drive voltage signal that causes the low side switching
element (Q1) to turn on, a reference voltage generating
circuit configured to generate a reference voltage
(triangular wave voltage signal) of which a voltage changes
along with a time that has elapsed since the drive voltage
signal has been outputted, and a turn off control unit
configured to switch the drive voltage signal to a voltage
at which the low side switching element (Q1) is turned off,
in response to the reference voltage reaching the feedback
voltage signal.

Preferably the transformer (T) includes a low side
drive winding (nbl), and that the drive voltage signal
output unit is configured to detect the inversion of the
voltage polarity in the transformer (T) on the basis of a
voltage at the low side drive winding (nbl).

Preferably the reference voltage generating circuit is
formed by a capacitor and a constant current circuit is
configured to charge the capacitor with a substantially
constant current in accordance with the drive voltage
signal, and a circuit is configured to discharge an electric
charge from the capacitor through a voltage of the drive
voltage signal that causes the low side switching element
(Q1) to turn off be provided.

If a PFC converter is to be formed, a full wave
rectifying circuit configured to accept input of a
commercial alternate current power supply voltage and
rectify the full waves of the commercial alternate current
power supply voltage may be provided, and an output voltage
of the full wave rectifying circuit is inputted to the power
supply voltage input unit.

Preferably the transformer includes a high side drive
winding (nb2), and a high side switching element control
circuit is configured to control the low side switching
element (Q1) and the high side switching element (Q2) such
that each of the two switching elements is turned on or off
in an alternating manner with a slight dead time during
which the two switching elements are both being turned off
be provided.

If a converter that includes the high side switching
element and the low side switching element is to be formed,
preferably the high side switching element control circuit
includes a turn on signal transmitting circuit configured to
supply a voltage generated in the high side drive winding
(nb2) to a control terminal of the high side switching
element (Q2) so as to turn on the high side switching
element (Q2) upon the low side switching element (Q1) being
turned off, a bidirectional constant current charge-
discharge circuit connected to the high side drive winding
(nb2) and configured to turn the voltage generated in the
high side drive winding (nb2) into a constant current and
charge or discharge a capacitor with the constant current, and a switching element (Q3) configured to turn off the high side switching element (Q2) by shifting a state upon a voltage at the capacitor charged by a voltage induced in the high side drive winding (nb2) exceeding a threshold value during an off time of the low side switching element (Q1).

Preferably a rectifying smoothing circuit is configured to rectify and smooth a voltage generated in the low side drive winding (nbl) to generate a direct current power supply voltage to be supplied to the switching control circuit be provided in the low side drive winding (nbl).

Embodiments of the present invention, can enable a single type of control IC to be used in a variety of power conversion circuits of a switching power supply device without providing individual switching control ICs for the respective configurations in the power conversion circuits of the switching power supply device. This ability makes it possible to simplify the configuration of the entire circuit.

Embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Fig. 1 is a circuit diagram of a switching power supply device indicated in JP 2001-37220 and described above;

Fig. 2 is a circuit diagram of a switching power supply
device 101 according to a first embodiment of the present invention;

Fig. 3 is a waveform diagram illustrating a relationship among a voltage \( V_{gs1} \) between a gate and a source of a low side switching element \( Q_1 \), a voltage \( V_{gs2} \) between a gate and a source of a high side switching element \( Q_2 \), a voltage \( V_{ds1} \) between a drain and the source of the low side switching element \( Q_1 \), and a voltage \( V_{cb2} \) at a capacitor \( C_{b2} \);

Fig. 4 is a waveform diagram illustrating a relationship between a voltage \( V_{nb2} \) at a high side drive winding \( nb2 \) and the voltage \( V_{cb2} \) at the capacitor \( C_{b2} \);

Fig. 5 is a circuit diagram of a switching power supply device 102 according to a second embodiment;

Fig. 6 is a circuit diagram of a switching power supply device 103 according to a third embodiment;

Fig. 7 is a circuit diagram of a switching power supply device 104 according to a fourth embodiment;

Fig. 8 is a circuit diagram of a switching power supply device 105 according to a fifth embodiment;

Fig. 9 is a circuit diagram of a switching power supply device 106 according to a sixth embodiment;

Fig. 10 is a circuit diagram of a switching power supply device 107 according to a seventh embodiment;

Fig. 11 is a circuit diagram of a switching power supply
supply device 108 according to an eighth embodiment;

Fig. 12 is a circuit diagram of a switching power supply device 109 according to a ninth embodiment;

Fig. 13 is a circuit diagram of a switching power supply device 110 according to a tenth embodiment;

Fig. 14 is a circuit diagram of a switching power supply device 111 according to an eleventh embodiment.

Detailed Description of Exemplary Embodiments

<<FIRST EMBODIMENT>>

A switching power supply device according to a first embodiment will be described with reference to Figs. 2 to 4.

Fig. 2 is a circuit diagram of a switching power supply device 101 according to the first embodiment. A voltage of a direct current input power supply Vi is inputted between input terminals PI(+) and PI(-) of the switching power supply device 101. Then, a predetermined direct current voltage is outputted to a load Ro that is connected between output terminals PO(+) and PO(-) of the switching power supply device 101.

A first series circuit, in which a capacitor Cr, an inductor Lr, a primary winding np of a transformer T, and a low side switching element Q1 are connected in series, is formed between the input terminals PI(+) and PI(-). The low side switching element Q1 is formed by an FET, and a drain
terminal thereof is connected to the primary winding np of the transformer T.

A second series circuit, in which a high side switching element Q2, the capacitor Cr, and the inductor Lr are connected in series, is formed between the two ends of the primary winding np of the transformer T.

A first rectifying smoothing circuit, which is formed by diodes Ds and Df and a capacitor Co, is formed on secondary windings ns1 and ns2 of the transformer T. This first rectifying smoothing circuit rectifies and smooths the full waves of an alternate current voltage that is outputted from the secondary windings ns1 and ns2 and outputs the result to the output terminals PO(+) and PO(-).

The transformer T includes not only the primary winding np and the secondary windings ns1 and ns2 but also a low side drive winding nb1 and a high side drive winding nb2.

A rectifying smoothing circuit, which is formed by a diode Db and a capacitor Cb, is connected to the low side drive winding nb1 of the transformer T. A direct current voltage obtained through this rectifying smoothing circuit is supplied to a VCC terminal of a switching control IC 84 as a power supply voltage.

The switching control IC 84 is a typical general purpose IC that includes an IS terminal (current detection terminal) and operates in a current mode.
A feedback circuit is provided between the output terminals PO(+) and PO(−) and the switching control IC 84. In Fig. 2, only a feedback path is indicated simply by a single line (Feedback). Specifically, however, a feedback signal is generated through a comparison of a divided voltage value of an output voltage Vo between the output terminals PO(+) and PO(−) against a reference voltage, and a feedback voltage is inputted to an FB terminal of the switching control IC 84 in an insulated state. The feedback voltage that is inputted to the FB terminal is higher as the output voltage Vo is lower.

A series circuit, which is formed by a constant current circuit CCl and a capacitor Cb1, is connected to an OUT terminal of the switching control IC 84 in such a manner that a charge voltage of the capacitor Cb1 is inputted to the IS terminal (current detection terminal).

In response to a voltage of a counter electromotive force that is induced in the low side drive winding nbl as the high side switching element Q2 is turned off being inputted to a ZT terminal (zero voltage timing detection terminal), the switching control IC 84 sets the OUT terminal to a high level. Through this, the low side switching element Q1 is turned on. The OUT terminal of the switching control IC 84 is connected to a control terminal of the low side switching element Q1 via a resistor R12.
The constant current circuit CCl charges the capacitor Cbl with a constant current through a voltage at the OUT terminal of the switching control IC 84. A comparator in the switching control IC 84 compares a voltage at the capacitor Cbl with a voltage at the FB terminal, and upon a voltage at the IS terminal exceeding the voltage at the FB terminal, the switching control IC 84 switches the voltage at the OUT terminal from the high level to a low level. Thus, as the voltage at the FB terminal is lower, the charge time in the capacitor Cbl decreases. In other words, an on time of the low side switching element Q1 becomes shorter, and the output voltage Vo is thus turned into a constant voltage.

Note that a diode D9 forms a discharge path of an electric charge from the capacitor Cbl. In other words, when the output voltage of the switching control IC 84 is brought to the low level (when Q1 is turned off), an electric charge in the capacitor Cbl is discharged via the diode D9.

In this manner, the circuit formed by the switching control IC 84, which is a current mode IC, the constant current circuit CCl, and the capacitor Cbl functions as a voltage-time conversion circuit. Then, a voltage of a feedback signal, which is generated by detecting the output voltage Vo and comparing the output voltage Vo with the
reference voltage (target voltage), is converted in the voltage-time conversion circuit, and the low side switching element Q1 is turned on for a period equivalent to the obtained time.

A second switching control circuit 61 is provided between the high side drive winding nb2 of the transformer T and the high side switching element Q2. The second switching control circuit 61 corresponds to a "high side switching element control circuit" in the appended claims. Specifically, a first end of the high side drive winding nb2 of the transformer T is connected to a node between the low side switching element Q1 and the high side switching element Q2 (source terminal of the high side switching element Q2), and the second switching control circuit 61 is connected between a second end of the high side drive winding nb2 and a gate terminal of the high side switching element Q2.

As will be described subsequently, the second switching control circuit 61 forces the high side switching element Q2 to turn off when a period that is equivalent to an on time of the low side switching element Q1 has elapsed after the high side switching element Q2 is turned on.

The second switching control circuit 61 is a bidirectional constant current circuit that is formed by a diode bridge rectifying circuit, which is formed by four
diodes D1, D2, D3, and D4, and a constant current circuit CC2, which is connected between a node between the diodes D1 and D3 and a node between the diodes D2 and D4, or in other words, connected between output ports of the diode bridge rectifying circuit.

When the low side switching element Q1 is turned on, a negative voltage induced in the high side drive winding nb2 causes a capacitor Cb2 to discharge with a constant current in a negative direction along a path formed by the capacitor Cb2, the diode D3, the constant current circuit CC2, the diode D2, and the high side drive winding nb2 in that order.

Thereafter, when the low side switching element Q1 is turned off, a positive voltage induced in the high side drive winding nb2 causes a positive voltage to be applied to the high side switching element Q2 via a resistor R5, and thus Q2 is turned on. In addition, the capacitor Cb2 is charged with a constant current in a positive direction along a path formed by the high side drive winding nb2, the diode D1, the constant current circuit CC2, the diode D4, and the capacitor Cb2 in that order. At a point in time when the voltage at the capacitor Cb2 exceeds a threshold voltage of a transistor, which is approximately 0.6 V, a transistor ("switching element" in the appended claims) Q3 is turned on, and in turn the high side switching element Q2 is turned off.
Through the operation described above, the discharge
time of the capacitor Cb2, or in other words, the on time of
the low side switching element Q1 becomes equal to the
charge time of the capacitor Cb2, or in other words, the on
time of the high side switching element Q2.

Fig. 3 is a waveform diagram illustrating a
relationship among a voltage Vgs1 between a gate and a
source of the low side switching element Q1, a voltage Vgs2
between a gate and a source of the high side switching
element Q2, a voltage Vds1 between the drain and the source
of the low side switching element Q1, and a voltage Vcb2 of
the capacitor Cb2.

Upon the low side switching element Q1 being turned on,
a negative voltage is induced in the high side drive winding
nb2, and the charge voltage Vcb2 of the capacitor Cb2 starts
to fall from the threshold voltage of approximately 0.6 V.
Thereafter, upon the low side switching element Q1 being
turned off, a positive voltage is induced in the high side
drive winding nb2, and the charge voltage Vcb2 of the
capacitor Cb2 starts to rise. When the charge voltage Vcb2
of the capacitor Cb2 exceeds the threshold voltage of
approximately 0.6 V, the transistor Q3 is turned on.
Through this, a gate potential of the high side switching
element Q2 becomes 0 V, and the high side switching element
Q2 is thus turned off. Since the capacitor Cb2 is charged
and discharged with a constant current of the same current value, the gradient of the charge voltage \( V_{\text{cbo2}} \) is even. In other words, a charge and discharge current ratio \( D_i \) is 1:1. Accordingly, the on time of the high side switching element \( Q2 \) is equal to the on time of the low side switching element \( Q1 \).

In Fig. 3, \( T_{\text{qon1}}(1) \) is equal to \( T_{\text{qon2}}(1) \) through the operation described above. Here, when the on time of the low side switching element \( Q1 \) increases to \( T_{\text{qon1}}(2) \), \( V_{\text{ds1}} \) and \( V_{\text{cbo2}} \) take on respective waveforms as indicated by the dotted lines. At this time as well, \( T_{\text{qon1}}(2) \) is equal to \( T_{\text{qon2}}(2) \) through the operation described above.

Fig. 4 is a waveform diagram illustrating a relationship between a voltage \( V_{\text{nbo2}} \) of the high side drive winding nb2 and the voltage \( V_{\text{cbo2}} \) of the capacitor Cb2.

In this manner, as the on time of the low side switching element \( Q1 \) changes, the on time of the high side switching element \( Q2 \) follows such a change and changes accordingly.

Note that as an electric charge is discharged from the capacitor Cb2, a reverse bias voltage is applied between a base and an emitter of the transistor Q3. A typical transistor, however, normally has a withstanding voltage of up to approximately -5 V and is thus capable of charging or discharging within a wide range of -4 V to 0.6 V even with a
design margin taken in consideration. If the range of a variation in the voltage at the capacitor Cb2 is increased, a permissible amount of external disturbance noise increases. In addition, and an error against a temperature change, a variation in the electrical characteristics of a component, and so on is reduced, which enables a stable operation.

According to the first embodiment, a voltage-time conversion circuit can be formed only by using a so-called current mode IC and providing, outside the current mode IC, a constant current circuit that charges a capacitor with a substantially constant current on the basis of a drive voltage signal of the low side switching element Q1. Thus, the on time of the low side switching element Q1 can be controlled in accordance with a feedback voltage, and the configuration of the entire circuit can be simplified.

Aside from the above, the following effects can be obtained.

(a) The low side switching element Q1 and the high side switching element Q2 can be turned on or off in an alternating manner with symmetric waveforms while having substantially the same amount of on time.

(b) A circuit for detection of the on time of the low side switching element Q1 and turning on and off the high side switching element Q2 can be integrated into a single
entity, and the second switching control circuit can be formed by a minimum number of discrete components.

(c) A potential at a ground terminal that is connected to the primary winding of the transformer T of the high side switching element Q2 varies along with switching of the low side switching element Q1, but the second switching control circuit 61 is a circuit that operates by using an alternate current voltage that is generated in the high side drive winding nb2. Therefore, a malfunction is less likely to occur regardless of the variation in the potential at the ground terminal.

[0045]

(d) The low side switching element Q1 and the high side switching element Q2 are turned on by using a change in the voltage that is generated in a transformer winding as a trigger and are turned on or off in an alternating manner with a minimum dead time. In other words, the two switching elements are not in the on state at the same time, and thus high reliability can be ensured. In addition, the dead time takes a minimum value that can achieve a ZVS (zero voltage switching) operation, and thus high power conversion efficiency can be obtained.

<<SECOND EMBODIMENT>>

Fig. 5 is a circuit diagram of a switching power supply device 102 according to a second embodiment.
The switching power supply device 102 differs from the switching power supply device 101 illustrated in Fig. 2 in terms of the configuration of a second switching control circuit 62. A constant current circuit is depicted with more details in the example illustrated in Fig. 5. Specifically, a base of a first transistor Q11 is connected to a collector of a second transistor Q12; an emitter of the first transistor Q11 is connected to a base of the second transistor Q12; a resistor R12 is connected between a collector and the base of the first transistor Q11; and a resistor R11 is connected between an emitter and the base of the second transistor Q12. Thus, a single constant current circuit is formed.

According to this configuration, the second switching control circuit can be formed by a minimum number of discrete components.

Note that, in the example illustrated in Fig. 5, a series circuit, which is formed by a resistor R6 and a diode D6, is connected in parallel to the resistor R5. Thus, a difference in impedance can be generated by differentiating a charge path used when charging the input capacitance of the high side switching element Q2 with an electric charge through a voltage generated in the high side drive winding nb2 and thus turning on the high side switching element Q2 from a discharge path used when discharging an electric
charge from the input capacitance of the high side switching element Q2. This allows such a design in which a delay time from a point in time when a change in the voltage occurs in the high side drive winding nb2 can be adjusted and the high side switching element Q2 can be turned on at an optimal timing.

<<THIRD EMBODIMENT>>

Fig. 6 is a circuit diagram of a switching power supply device 103 according to a third embodiment.

The switching power supply device 103 differs from the switching power supply device 101 illustrated in Fig. 2 in terms of the configuration of a switching control circuit at the low side and the configuration of a second switching control circuit 63.

In the switching control circuit at the low side according to this embodiment, a constant voltage circuit, which is formed by a resistor R13 and a Zener diode Dz4, is formed at the OUT terminal of the switching control IC 84. A time constant circuit, which is formed by a resistor R14 and the capacitor Cbl, is connected to the Zener diode Dz4. A resistive divider circuit, which is formed by resistors R15 and R16, is connected between the two ends of the capacitor Cbl. An output voltage of this resistive divider circuit is inputted to the IS terminal of the switching control IC 84.
In this manner, the time constant circuit may be charged with a constant voltage. In addition, the voltage at the capacitor Cb1 serving to set a time constant may be divided through resistors and inputted to the IS terminal of the switching control IC.

In the second switching control circuit 63 according to this embodiment, capacitors C1, C2, C3, and C4 are connected in parallel to the diodes D1, D2, D3, and D4, respectively. In this manner, connecting the capacitors in parallel to the respective diodes that rectify currents inputted to and outputted from the constant current circuit CC2 makes it possible to accumulate electric charges in the capacitors C1, C2, C3, and C4 during a period in which a reverse voltage is applied to a rectifying diode and to discharge electric charges accumulated in the capacitors C1, C2, C3, and C4 during a dead time in which a voltage at the high side drive winding nb2 changes. As a result, a current can be made to flow with a leading phase relative to the diodes. This makes it possible to adjust an amount of current charged to or discharged from the capacitor Cb2, and distortion of a charge or discharge current generated during a dead time, or in particular, generated while the direction of the current being charged to or discharged from the capacitor Cb2 changes can be corrected. Note that the capacitors do not necessarily have to be connected in
parallel to all of the respective diodes D1 to D4, and the distortion of the charge or discharge current can be corrected as long as a capacitor is connected in parallel to at least one of the diodes D1 to D4.

<<FOURTH EMBODIMENT>>

Fig. 7 is a circuit diagram of a switching power supply device 104 according to a fourth embodiment.

The switching power supply device 104 differs from the switching power supply device 101 illustrated in Fig. 2 in terms of the configuration of a second switching control circuit 65. In this example, the capacitors C1 and C2 are connected in parallel to the diodes D1 and D2, respectively. In addition, resistors R3 and R4 are connected in parallel to the diodes D3 and D4, respectively.

Creating a difference in the resistance values of the respective resistors R3 and R4 makes it possible to create a difference in impedance (time constant) between a charge path to and a discharge path from the capacitor Cb2. Thus, a slight difference in the on times between the low side switching element Q1 and the high side switching element Q2 can be corrected. In addition, adjusting the resistance value by using the resistors R3 and R4 makes it possible to correct a slight difference in the on time which is required when an input voltage or output voltage changes. In other words, the resistance value is adjusted by using the
resistors R3 and R4 while making use of a change in the voltage at the high side drive winding nb2. A current that is determined by the voltage at the high side drive winding nb2 and the resistor R3 or R4 is added to a current that is determined by the constant current circuit so as to be superimposed thereon, and the result is then set as a current to be charged to or discharged from the capacitor Cb2. Thus, correction can be made when an input or output voltage changes. Through this, the on times of the low side switching element Q1 and of the high side switching element Q2 can be made equal in duration with higher precision.

Note that a resistor may be connected in parallel to at least one of the diodes D1 to D4. Note also that a capacitor may be connected at a location at which a resistor is not connected in parallel to a diode.

<<FIFTH EMBODIMENT>>

Fig. 8 is a circuit diagram of a switching power supply device 105 according to a fifth embodiment.

The switching power supply device 105 differs from the switching power supply device of the first embodiment illustrated in Fig. 2 in terms of the configuration of the transformer T at the secondary side.

In the fifth embodiment, a diode bridge circuit, which is formed by diodes D21, D22, D23, and D24, and the capacitor Co are connected to a secondary winding ns of the
transformer T.

In this manner, the full waves may be rectified by the diode bridge circuit.

<<SIXTH EMBODIMENT>>

Fig. 9 is a circuit diagram of a switching power supply device 106 according to a sixth embodiment.

The switching power supply device 106 differs from the switching power supply device of the first embodiment illustrated in Fig. 2 in terms of the configuration of the transformer T at the secondary side.

In the sixth embodiment, the diode Ds and the capacitor C01 and the diode Df and the capacitor C02 are connected respectively between the two ends of the respective secondary windings ns1 and ns2 of the transformer T, and a node between the capacitors C01 and C02 is connected to a node between the secondary windings ns1 and ns2. In addition, a capacitor C03 is connected between the output terminals PO(+) and PO(-).

In this manner, a voltage doubling rectifying circuit may be constituted.

<<SEVENTH EMBODIMENT>>

Fig. 10 is a circuit diagram of a switching power supply device 107 according to a seventh embodiment.

The switching power supply device 107 differs from the switching power supply device of the first embodiment
illustrated in Fig. 2 in terms of the location of the capacitor Cr.

The resonance capacitor Cr may be disposed at any location along a path of a current that flows toward the inductor Lr when the low side switching element Q1 is turned off. Thus, as illustrated in Fig. 10, the capacitor Cr may be connected between one end of the primary winding np and the source of the high side switching element Q2.

<<EIGHTH EMBODIMENT>>

Fig. 11 is a circuit diagram of a switching power supply device 108 according to an eighth embodiment.

The switching power supply device 108 differs from the switching power supply device of the first embodiment illustrated in Fig. 2 in terms of the location of the capacitor Cr.

The resonance capacitor Cr may be disposed at any location along a path of a current that flows toward the inductor Lr when the low side switching element Q1 is turned off. Thus, as illustrated in Fig. 11, the capacitor Cr may be connected between the drain of the high side switching element Q2 and the input terminal PI(+).

<<NINTH EMBODIMENT>>

Fig. 12 is a circuit diagram of a switching power supply device 109 according to a ninth embodiment.

The switching power supply device 109 differs from the
switching power supply device of the first embodiment illustrated in Fig. 2 in that a series circuit, which is formed by a capacitor Cr1 and the inductor Lr, is provided between the drain of the switching element Q2 and one end of the primary winding np of the transformer T and a capacitor Cr2 is provided between a node between the capacitor Cr1 and the inductor Lr and a ground line as well.

The capacitor Cr1 is provided such that the inductor Lr, the primary winding np, the high side switching element Q2, and the capacitor Cr1 form a closed loop. In addition, Cr2 is connected in series to the high side switching element Q2 and the capacitor Cr1.

In this manner, connecting the capacitor Cr2 allows a current supplied from the power supply voltage Vi to flow during the on time of the low side switching element Q1 as well as during the on time of the high side switching element Q2. Such a configuration reduces an effective current of the current supplied from the power supply voltage Vi as compared with a circuit configuration in which the current flows only during the on time of the low side switching element Q1. Thus, a conduction loss of the current supplied from the power supply voltage Vi can be reduced.

<<TENTH EMBODIMENT>>

Fig. 13 is a circuit diagram of a switching power
supply device 110 according to a tenth embodiment.

The switching power supply device 110 differs from the switching power supply device of the first embodiment illustrated in Fig. 2 in terms of the locations of the high side switching element Q2 and the capacitor Cr.

The resonance capacitor Cr may be disposed at any location along a path of a current that flows toward the inductor Lr when the low side switching element Q1 is turned off. Thus, as illustrated in Fig. 13 the capacitor Cr may be connected between the drain of the high side switching element Q2 and the input terminal PI(-).

<<ELEVENTH EMBODIMENT>>

Fig. 14 is a circuit diagram of a switching power supply device 111 according to an eleventh embodiment. The switching power supply device 111 functions as a power factor correction converter (PFC converter).

The switching power supply device 111 includes a diode bridge circuit DB that accepts input of an alternate current voltage of a commercial alternate current power supply AC and rectifies the full waves thereof. The switching power supply device 111 further includes a capacitor Ci, which serves as a low pass filter. The low side switching element Q1 is formed by an FET, and the drain terminal of the low side switching element Q1 is connected to the primary winding np of the transformer T. A rectifying smoothing
circuit, which is formed by the diode Ds and the capacitor Co, is formed at the secondary winding nsl of the transformer T. This rectifying smoothing circuit rectifies and smooths an alternate current voltage outputted from the secondary winding nsl and outputs the result to the output terminals PO(+) and PO(-).

Another rectifying smoothing circuit, which is formed by a diode Db and a capacitor Cb, is connected to the low side drive winding nbl of the transformer T. A direct current voltage obtained through this rectifying smoothing circuit is supplied to the VCC terminal of the switching control IC 84 as a power supply voltage.

A feedback circuit is provided between the output terminals PO(+) and PO(-) and the switching control IC 84. In Fig. 14, only a feedback path is indicated simply by a single line (Feed back).

A series circuit, which is formed by the constant current circuit CCl and the capacitor Cbl, is connected to the OUT terminal of the switching control IC 84 in such a manner that a charge voltage of the capacitor Cbl is inputted to the IS terminal (current detection terminal).

The switching control circuit that is connected to the gate of the low side switching element Q1 is identical to the one described in the first embodiment.

If the charge voltage of the capacitor Cbl is currently
lower than the voltage inputted to the FB terminal, the OUT terminal is set to the high level, and the switching element Q1 is turned off. In addition, the voltage at the OUT terminal at the high level is applied to the constant current circuit CCl, and the capacitor Cbl is thus charged with a constant current. If the potential at the capacitor Cbl exceeds the potential at the FB terminal, the OUT terminal is inverted to the low level. Through this, the switching element Q1 is turned off. In addition, the electric charge in the capacitor Cbl is discharged via the diode D9.

Thereafter, if the potential at the IS terminal falls below the potential at the FB terminal due to the electric charge discharge from the capacitor Cbl, the OUT terminal is set to the high level, and the switching element Q1 is thus turned on again.

Through the repetition of the operations described above, the switching element Q1 operates intermittently, and the on time thereof changes in accordance with the feedback voltage. The on time of the switching element Q1 is constant at a frequency in the range of the frequency of the commercial alternate current power supply. Therefore, a peak value of the current that flows in the power conversion circuit changes in accordance with the variation in the input voltage of the commercial alternate current power supply.
supply, and the envelope of the peak value takes on a sinusoidal waveform. At this time, an external shape of the input current that flows in through the low pass filter takes on a sinusoidal waveform, and the input current contains little amount of harmonic current component. Thus, the converter operates as the power factor correction (PFC) converter that suppresses the harmonic current component to a great extent.

It should be noted that although a rectifying circuit formed by a diode is formed as a circuit at the secondary side of the transformer T in each of the embodiments described above, in place of the diode, a rectifying FET may be provided to rectify synchronously. Through this, a loss in the secondary side circuit can be reduced.

Reference Signs List

Cb1, Cb2  CAPACITORS
CC1, CC2 CONSTANT CURRENT CIRCUITS
D1 to D4, D6, D9  DIODES
Db  DIODE
DB  DIODE BRIDGE CIRCUIT
Ds, Df  DIODES
Dz4  ZENER DIODE
Lr  INDUCTOR
nb1  LOW SIDE DRIVE WINDING
nb2  HIGH SIDE DRIVE WINDING
np   PRIMARY WINDING
ns1, ns2  SECONDARY WINDINGS
Q1  LOW SIDE SWITCHING ELEMENT
Q2  HIGH SIDE SWITCHING ELEMENT
T  TRANSFORMER
Vi  DIRECT CURRENT INPUT POWER SUPPLY
Vo  OUTPUT VOLTAGE
61 to 63  SECOND SWITCHING CONTROL CIRCUITS
65  SECOND SWITCHING CONTROL CIRCUIT
101 to 111  SWITCHING POWER SUPPLY DEVICES
CLAIMS

1. A switching power supply device, comprising:
   a power supply voltage input unit configured to accept input of an input power supply voltage;
   a direct current voltage output unit configured to receive output of a direct current voltage;
   a transformer including a primary winding and a secondary winding;
   a low side switching element connected in series to the primary winding and configured to apply a voltage at the power supply voltage input unit to the primary winding upon being turned on;
   a switching control circuit configured to control the low side switching element;
   a rectifying smoothing circuit configured to rectify and smooth a voltage outputted from the secondary winding and output an output voltage to the direct current voltage output unit; and
   a feedback voltage signal generating circuit configured to generate a feedback voltage signal on the basis of the output voltage,
   wherein the switching control circuit includes a drive voltage signal output unit configured to output, upon detecting an inversion of a voltage polarity in
the transformer, a drive voltage signal that causes the low side switching element to turn on,

a reference voltage generating circuit configured to generate a reference voltage of which a voltage changes along with a time that has elapsed since the drive voltage signal has been outputted, and

a turn off control unit configured to switch the drive voltage signal to a voltage at which the low side switching element is turned off, in response to the reference voltage reaching the feedback voltage signal.

2. The switching power supply device according to claim 1, wherein the transformer includes a low side drive winding, and

wherein the drive voltage signal output unit is configured to detect the inversion of the voltage polarity in the transformer on the basis of a voltage at the low side drive winding.

3. The switching power supply device according to claim 1 or 2,

wherein the reference voltage generating circuit is formed by a capacitor and a constant current circuit configured to charge the capacitor with a substantially constant current in accordance with the drive voltage
signal, and

wherein a circuit configured to discharge an electric charge from the capacitor through a voltage of the drive voltage signal that causes the low side switching element to turn off is provided.

4. The switching power supply device according to any one of claims 1 to 3:

wherein a full wave rectifying circuit configured to accept input of a commercial alternate current power supply, to rectify the full waves of the commercial alternate current power supply, and to input the result to the power supply voltage input unit is provided.

5. The switching power supply device according to any one of claims 1 to 4,

wherein the transformer includes a high side drive winding, and

wherein a high side switching element control circuit configured to control the low side switching element and the high side switching element such that each of the two switching elements is turned on or off in an alternating manner with a slight dead time during which the two switching elements are both turned off is provided.
6. The switching power supply device according to claim 5, wherein the high side switching element control circuit includes

a turn on signal transmitting circuit configured to supply a voltage generated in the high side drive winding to a control terminal of the high side switching element so as to turn on the high side switching element upon the low side switching element being turned off,

a bidirectional constant current charge-discharge circuit connected to the high side drive winding and configured to turn the voltage generated in the high side drive winding into a constant current and charge or discharge a capacitor with the constant current, and

a switching element configured to turn off the high side switching element by shifting a state upon a voltage at the capacitor charged by a voltage induced in the high side drive winding exceeding a threshold value during an off time of the low side switching element.

7. The switching power supply device according to any one of claims 1 to 6,

wherein a rectifying smoothing circuit configured to rectify and smooth a voltage generated in the low side drive winding to generate a direct current power supply voltage to
be supplied to the switching control circuit is provided in the low side drive winding.

8. A switching power supply device substantially as herein described with reference to any of figures 2 to 14 of the accompanying drawings.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

H02M3/338(2006.01)i, H02M3/28(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H02M3/00-3/44

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

Jitsuyo Shinan Koho 1922-1996
Jitsuyo Shinan Toroku Koho 1996-2012
Kokai Jitsuyo Shinan Koho 1971-2012
Toroku Jitsuyo Shinan Koho 1994-2012

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>X</td>
<td>JP 2008-289336 A (Murata Mfg. Co., Ltd.), 27 November 2008 (27.11.2008), paragraphs [0055] to [0059], [0093] to [0094]; fig. 3 to 4, 10 &amp; US 2008/0291702 A1 paragraphs [0074] to [0078], [0113] to [0117]; fig. 3 to 4, 10</td>
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☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance.

“E” earlier application or patent but published on or after the international filing date.

“L” later document published prior to the international filing date but later than the priority date claimed.

“O” document referring to an oral disclosure, use, exhibition or other means of communication.

“P” document published prior to the international filing date but later than the priority date claimed.

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention.

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone.

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

“&” document member of the same patent family.

Date of the actual completion of the international search

23 October, 2012 (23.10.12)

Date of mailing of the international search report

30 October, 2012 (30.10.12)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)
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<td>Y</td>
<td>JP 2008-125217 A (Fuji Electric Device Technology Co., Ltd.), 29 May 2008 (29.05.2008), paragraphs [0005], [0012] to [0017]; fig. 1 to 4, 8, 15 &amp; US 2008/0112192 A1 paragraphs [0004], [0027] to [0035]; fig. 1 to 4, 8, 15</td>
<td>6</td>
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<tr>
<td>A</td>
<td>JP 8-289542 A (Matsushita Electric Industrial Co., Ltd.), 01 November 1996 (01.11.1996), fig. 5 to 6 (Family: none)</td>
<td>3</td>
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<tr>
<td>A</td>
<td>JP 2006-109566 A (Fuji Electric Device Technology Co., Ltd.), 20 April 2006 (20.04.2006), abstract; paragraph [0020]; fig. 5 (Family: none)</td>
<td>6</td>
</tr>
</tbody>
</table>
INTERNATIONAL SEARCH REPORT

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2.☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
   See extra sheet.

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2.☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
☐ The additional search fees were accompanied by the applicant’s protest and, where applicable, the payment of a protest fee.
☐ The additional search fees were accompanied by the applicant’s protest but the applicable protest fee was not paid within the time limit specified in the invitation.
☐ No protest accompanied the payment of additional search fees.
It was revealed that all of the technical features which the invention of claim 1 have are not novel, since said all the technical features are disclosed in the following document 1 or document 2.

As a result, said matter is not a “special technical feature” within the meaning of PCT Rule 13.2, second sentence, since the matter does not make a contribution over the prior art.


Document 2: JP 2008-289336 A (Murata Mfg. Co., Ltd.), 27 November 2008 (27.11.2008), paragraphs [0055] to [0059], [0093] to [0094], fig. 3 to 4, 10 & US 2008/0291702 A1, paragraphs [0074] to [0078], [0113] to [0117], fig. 3 to 4, 10

Consequently, it is not considered that there is a technical relationship involving a same or corresponding “special technical feature” among the inventions of claims 1-7.

In conclusion, this international application does not comply with the requirement of unity of invention prescribed under PCT Rules 13.1.

Meanwhile, the parts concerning main invention are the invention of claim 3, and the parts of the inventions of claims 4-7 which are dependent on claim 3.

Furthermore, also the inventions of claims 1 and 2 having no “special technical feature” can be added to the parts concerning the main invention, since the search on said invention has been completed.