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Control circuit, DC-DC converter, and energy harvesting system

Abstract

There is provided a control circuit which controls a DC-DC converter which boosts an output voltage of an input source and outputs the output voltage which has been boosted, in which the DC-DC converter has a boost coil, and a capacitor, and the control circuit includes: an input terminal into which the output voltage is input; a first transistor arranged between the input terminal, and the boost coil and the capacitor; and a switch activation unit which boosts the output voltage, and applies the output voltage, which has been boosted, to a control terminal of the first transistor.

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Background/Summary

(1) The contents of the following patent application(s) are incorporated herein by reference: NO. 2023-032158 filed in JP on Mar. 2, 2023 NO. 2023-192001 filed in JP on Nov. 10, 2023

BACKGROUND

1. Technical Field

(2) The present invention relates to a control circuit, a DC-DC converter, and an energy harvesting system.

2. Related Art

(3) In the related art, an MPPT control circuit is known to have a first switch arranged in series between an RF-DC conversion circuit and a DC-DC converter. (Refer to Patent Document 1, for example).

PRIOR ART DOCUMENT

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 is a diagram showing an energy harvesting system **100** according to a first example of the present invention.

(2) FIG. 2 is a diagram showing a change over time in each voltage when a boost operation is started.

(3) FIG. 3 is a diagram showing an example of a switch activation unit **18**.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

(4) Hereinafter, the invention will be described through embodiments of the invention, but the following embodiments do not limit the invention according to claims. In addition, not all of the combinations of features described in the embodiments are essential to the solving means of the invention. In the present specification, the same parts in each figure are denoted by the same signs and numerals, and the descriptions thereof may be omitted. In addition, for convenience of description, some configurations may not be illustrated.

(5) In the present specification, a case where a term such as “same” or “equal” is mentioned may include a case where an error due to a variation in manufacturing or the like is included. The error is, for example, within 10%. In addition, each terminal and component in the figure may be connected by using wiring or the like. Each ground terminal in the figure may be a common terminal or may be a separate terminal.

(6) For electric power obtained from an energy harvesting source and the like, the power is typically low, a voltage and a current that can be extracted are low, and the power changes greatly over time due to a change in an environment thereof. A DC-DC converter is used to collect such a small amount of power, and boost the collected power to a voltage at which a sensor, a microcomputer, BLE, or the like is able to be operated.

(7) FIG. 1 is a diagram showing an energy harvesting system **100** according to a first example of the present invention. The energy harvesting system **100** supplies power to an external device. The energy harvesting system **100** includes an input source **80** and a DC-DC converter **90**. The input source **80** outputs an output voltage V_{in} to the DC-DC converter **90**. The DC-DC converter **90** boosts the output voltage V_{in} of the input source **80** and outputs the boosted output voltage V_{in} . The DC-DC converter **90** is, for example, a step-up DC-DC converter.

(8) The input source **80** may be the energy harvesting source, or may be a wireless power transfer. For example, the energy harvesting source is for: photovoltaic power generation which uses, as an energy source, light energy from sunlight, an incandescent lamp, a fluorescent lamp, an LED, or the like; heat power generation which uses, as the energy source, heat energy from heat generated by machinery, environment temperature, or the like; vibration power generation which uses, as the energy source, vibration generated by machinery or vibration of a bridge, a road, or the like; electromagnetic wave power generation which uses, as energy, an electromagnetic wave, an electric wave, or the like; organism power generation which is represented by a microbial fuel cell and which converts an amount of activity of a living being into the energy; and others. For the input source **80**, an amount of power generation may change over time depending on the surrounding environment or the like.

(9) The DC-DC converter **90** includes a control circuit **10**, a boost coil **40**, a first capacitor **41**, and a second capacitor **42**. The control circuit **10** controls the DC-DC converter **90**. The control circuit **10** may be included in the DC-DC converter **90**. The second capacitor **42** is charged by a boost operation of the DC-DC converter **90** which will be described below. In this manner, a boost

voltage V_{boost} of the DC-DC converter **90** rises. The first capacitor **41** is connected to one end of the boost coil **40** to efficiently perform the boost operation.

(10) The DC-DC converter **90** of the present example has a BATT terminal and a VSYS terminal. The BATT terminal may be connected to a battery (a third capacitor **43** in FIG. 1) included in the external device. The VSYS terminal is connected to a circuit of the external device and supplies source power to the circuit of the external device. In FIG. 1, a capacitor connected to the VSYS terminal is shown as a fourth capacitor **44**.

(11) The BATT terminal is connected to the second capacitor **42** via a third switch M3 of the control circuit **10**. The VSYS terminal is connected to the second capacitor **42** via a fourth switch M4 of the control circuit **10**. By controlling the third switch M3 and the fourth switch M4, supplying the power of the second capacitor **42** is switched to any between the BATT terminal or the VSYS terminal. In addition, the power may be supplied from the third capacitor **43** to the VSYS terminal by setting the third switch M3 and the fourth switch M4 to be in an on state at the same time.

(12) The boost voltage V_{boost} is output to the external device via the fourth switch M4 and the terminal VSYS. Capacitance $C_{sub.VSYS}$ of the fourth capacitor **44** may be less than a sum of capacitance $C_{sub.BOOST}$ of the second capacitor **42** and capacitance $C_{sub.BATT}$ of the third capacitor **43**.

(13) The control circuit **10** includes a boost switch **46** and a second switch M2. One end of the boost switch **46** is connected to the boost coil **40**, and the other end is connected to the ground terminal. One end of the second switch M2 is connected to the boost coil **40**, and the other end is connected to the second capacitor **42**. The boost switch **46** and the second switch M2 are controlled in a complementary manner such that when one is in the on state, the other is in an off state. Alternatively, both of the boost switch **46** and the second switch M2 are controlled to be in the off state, or both are controlled to be in the on state. The boost switch **46** and the second switch M2 are, for example, an N channel MOSFET and a P channel MOSFET in which turning on and turning off are controlled by a drive signal. When the boost switch **46** is turned on and the second switch M2 is turned off by the drive signal, the current flows from an input terminal **12** to the ground terminal via the boost coil **40** and the boost switch **46**, and the energy is stored in the boost coil **40**. When the boost switch **46** is turned off and the second switch M2 is turned on, the energy stored in the boost coil **40** is charged to the second capacitor **42** via the second switch M2, and the boost voltage V_{boost} rises.

(14) The control circuit **10** has a DC-DC control unit **48**. The DC-DC control unit **48** is connected to each control terminal of the boost switch **46**, the second switch M2, the third switch M3, and the fourth switch M4; and controls the turning on and the turning off of each switch. The DC-DC control unit **48** controls the boost operation by controlling the turning on and the turning off of the boost switch **46**. By controlling the turning on and the turning off of the third switch M3 and the fourth switch M4, the DC-DC control unit **48** performs a control regarding whether to output the boost voltage V_{boost} to the third capacitor **43** (the BATT terminal) or to output the boost voltage V_{boost} to the external device (the VSYS terminal) as described above, or to perform both. When the output by the boost operation is not sufficient, an electric charge stored in the third capacitor **43** may be output to the external device.

(15) Each switch may be a MOSFET, and may have a body diode. Each switch may have two MOSFETs connected such that directions of body diodes are directions opposite to each other. In that case, source terminals of the two MOSFETs may be connected to each other, and drain terminals may be connected to each other.

(16) Here, a technology called MPPT (Maximum Power Point Tracking) will be described. The MPPT is a generic term for technologies in which an operation is performed at an optimal operating point to extract the maximum power of the energy harvesting source or the like represented by a solar cell. By calculating an operating point at which the energy of the energy

harvesting source or the like can be efficiently extracted, and driving the DC-DC converter **90** at this operating point, an efficient energy conversion is possible. The control circuit **10** of the present example has an MPPT function. The DC-DC converter **90** of the present example performs an MPPT operation.

(17) When the optimal operating point is searched for, an energy conversion circuit of the DC-DC converter **90** is temporarily powered off, and an open-circuit voltage V_{source} of the input source **80** is measured. Alternatively, by connecting any load, output impedance R_{source} of the input source **80** is measured. By calculating the operating point for efficiently extracting the energy of the input source **80** according to the obtained measured value, and operating the DC-DC converter **90** according to the calculated operating point, it is possible to match the output impedance of the input source **80** with input impedance of the DC-DC converter **90**, and to efficiently perform the energy conversion.

(18) When the output impedance R_{source} of the input source **80** is measured by connecting the load for measurement, only the load for measurement is set in a state of being connected, and thus it is preferable for the first capacitor **41** or the like of the DC-DC converter **90** to be blocked from the input source **80**. For example, when the load for measurement and the first capacitor **41** are in a state of being connected in parallel, the open-circuit voltage V_{source} is not stabilized until the first capacitor **41** is charged, and it takes time to measure the output impedance R_{source} . When the output impedance R_{source} of the input source **80** has a high resistance ($k\Omega$ or more) and a drive force is small, this effect is noticeable.

(19) For example, when capacitance of the first capacitor **41** is set to $10\ \mu F$ and the output impedance R_{source} of the input source **80** is set to $10\ k\Omega$, it may take several hundred milliseconds for the open-circuit voltage V_{source} to be stabilized such that it takes time to measure the open-circuit voltage V_{source} . A period of measuring the open-circuit voltage V_{source} or the output impedance R_{source} of the input source **80** is set as an operating period (period) of the MPPT, and a time it takes for one measurement thereof is set as an operating time (duration). In the operating period of the MPPT, a time other than the operating time of the MPPT corresponds to a time during which the DC-DC converter **90** performs the boost operation. In order to secure the operating time of the DC-DC converter **90**, the operating period of the MPPT has a predetermined ratio to the operating time of the MPPT. When the ratio of the operating period to the operating time of MPPT is set to 50 times, the MPPT operation can only be performed at a period of 10 seconds (several hundred milliseconds \times 50), and there is a problem that it is not possible to follow, in a high speed, the change in the power generation of the input source **80**. This is not suitable particularly when the input source **80** is an energy harvesting source that is sensitive to the environmental change.

(20) On the other hand, it is preferable for the first capacitor **41** to have a large capacity for high efficiency of boosting. For example, it is desirable to have capacitance on the order of several μF to several tens of μF . Therefore, in order to achieve the high efficiency of boosting and a high speed response of the MPPT, it is preferable to block the first capacitor **41**, the boost coil **40**, or the like from the input terminal **12** at a time of the MPPT. Specifically, a switch is provided between the input terminal **12** and a SWIN terminal to block a path at the time of the MPPT. As a result, the capacitance of the first capacitor **41** connected to the SWIN terminal is interrupted from the input terminal **12**, and thus the operating point converges instantly even when the output impedance R_{source} is high. That is, it becomes possible to measure the output impedance R_{source} in a short time, and the operating time can be shortened. Since the operating time of the MPPT is short, the operating period of the MPPT can be shortened.

(21) The control circuit **10** includes the input terminal **12** to which the output voltage V_{in} is input, and a first transistor **14** arranged between the input terminal **12** and the boost coil **40**. This first transistor **14** is arranged between the input terminal **12** and the first capacitor **41**. At the time of the MPPT operation, the first transistor **14** blocks the first capacitor **41** and the boost coil **40**, from the input terminal **12**. This makes it possible to perform the MPPT operation with a high frequency

while the ratio between the operating period and the operating time of the MPPT is sufficiently maintained, and makes it possible to more efficiently convert even the energy of the input source **80** whose power generation capacity always changes. The first transistor **14** may be connected between a node **52** between one end of the boost coil **40** and one end of the first capacitor **41**, and a node **54** between the input terminal **12** of the control circuit **10** and an input terminal of a switch activation unit which will be described below.

(22) The first transistor **14** may be able to block all the capacitors included in the DC-DC converter **90** from the input terminal **12**. At the time of the MPPT operation, the first transistor **14** may block all the capacitors from the input terminal **12**.

(23) However, in an initial stage of the boost operation before the MPPT operation, the second capacitor **42**, the third capacitor **43**, and the fourth capacitor **44** are not charged with the electric charges. The boost voltage V_{boost} is also started from a low state or a state in which the voltage is zero. Therefore, when the output voltage V_{in} of the input source **80** is lower than a threshold voltage of the first transistor **14**, the first transistor **14** cannot be turned on. Therefore, for the DC-DC converter **90**, the boost operation is not possible. In addition, even when the first transistor **14** is set to be turned on, a value of the voltage applied to a control terminal **16** of the first transistor **14** is not sufficiently high, and thus an on-resistance of the first transistor **14** is high and power conversion efficiency is poor.

(24) In the input source **80** such as an RF energy harvester having a high output impedance, that is, a low power generation capacity, there is also a problem that the optimal operating point is shifted due to a leakage current of the first transistor **14**. Therefore, it is preferable to use, as the first transistor **14**, a transistor with a low leakage current, that is, a high off resistance. When a transistor with a low threshold voltage is used, a switching operation is possible with a low control voltage; however, the leakage current becomes high.

(25) The control circuit **10** of the present example includes a switch activation unit **18** which boosts the output voltage V_{in} of the input source **80**, and applies the output voltage V_{in} , which has been boosted, to the control terminal **16** of the first transistor **14**. The switch activation unit **18** applies, to the control terminal **16**, a switch activation voltage V_{cp} that is a boosted voltage. The switch activation unit **18** includes a charge pump as an example. The switch activation voltage V_{cp} may be higher than the threshold voltage of the first transistor **14**, may be 1.2 times or more of the threshold voltage, and may be 1.5 times or more. The switch activation voltage V_{cp} may be twice or more of the output voltage V_{in} , may be three times or more, or may be five times or more. In this manner, the boost operation from a low voltage is possible.

(26) The first transistor **14** may be the N channel MOSFET. The first transistor **14** may have a body diode. In the first transistor **14**, two N channel MOSFETs may have a cascade connection such that the directions of the body diodes are directions opposite to each other. In that case, source terminals of the two MOSFETs may be connected to each other, and drain terminals may be connected to each other.

(27) The control circuit **10** may have a high voltage selector circuit **20** which selects the voltage that is applied to the control terminal **16** of the first transistor **14**. The high voltage selector circuit **20** selects whichever is higher of the switch activation voltage V_{cp} boosted by the switch activation unit **18**, and the boost voltage V_{boost} boosted by the boost operation of the DC-DC converter **90**. The boost voltage V_{boost} is supplied from an MPPT control circuit **22** which will be described below. In this manner, in the initial stage of the boost operation before the MPPT operation, it is possible to start the boost operation by the switch activation voltage V_{cp} ; and when the boost voltage V_{boost} sufficiently rises, it is possible to switch to the MPPT operation, and to control the first transistor **14** by the boost voltage V_{boost} .

(28) When the boost voltage V_{boost} rises to a predetermined voltage, the switch activation unit **18** may be brought into the off state. The predetermined voltage may be a voltage at which the MPPT operation is possible, and may be equal to or higher than the switch activation voltage V_{cp} .

(29) The control circuit **10** may further include the MPPT control circuit **22** which outputs the boost voltage V_{boost} to the high voltage selector circuit **20**. The MPPT control circuit **22** outputs, to the high voltage selector circuit **20**, the boost voltage V_{boost} or a reference voltage lower than the boost voltage V_{boost} . The reference voltage may be 0V.

(30) The control circuit **10** may have a second transistor **24** which is the P channel MOSFET arranged in parallel with the first transistor **14**. The second transistor **24** is arranged between the SWIN terminal and the IN terminal. The output voltage V_{in} of the input source **80** may be applied to a source terminal **28** or a drain terminal of the second transistor **24**. The second transistor **24** may have a body diode. In the second transistor **24**, two P channel MOSFETs may have a cascade connection such that the directions of the body diodes are directions opposite to each other. In that case, source terminals of the two MOSFETs may be connected to each other, and drain terminals may be connected to each other.

(31) The output voltage V_{in} is applied to the source terminal **28** of the second transistor **24** in the present example. The MPPT control circuit **22** outputs, to a control terminal **26** of the second transistor **24**, the boost voltage V_{boost} or the reference voltage lower than the boost voltage V_{boost} . The MPPT control circuit **22** may output a control signal for causing the first transistor **14** and the second transistor **24** to transition to the on state in synchronization, and to transition to the off state in synchronization.

(32) The MPPT control circuit **22** measures the input source **80**. The MPPT control circuit **22** may measure the open-circuit voltage V_{source} or the output impedance R_{source} of the input source **80**. The DC-DC control unit **48** controls the operation of the DC-DC converter **90** based on a measurement result in the MPPT control circuit **22**. The DC-DC control unit **48** may control the operation of the DC-DC converter **90** to have the operating point (the input voltage) of the DC-DC converter **90** in accordance with the value of the measured open-circuit voltage V_{source} . The DC-DC control unit **48** may control the operation of the DC-DC converter **90** such that the value of the measured output impedance R_{source} matches the input impedance of the DC-DC converter **90**. The controlling of the operation of the DC-DC converter **90** means, as an example, adjusting timings of the turning on and the turning off of the boost switch **46**.

(33) FIG. 2 is a diagram describing a change over time in each voltage when a boost operation is started. The horizontal axis of each graph in FIG. 2 represents a time, and the vertical axis represents a voltage. The graph shows, from the top, the output voltage V_{in} , the switch activation voltage V_{cp} , the boost voltage V_{boost} , an application voltage $N1$ of the control terminal **16**, and an application voltage $N2$ of the control terminal **26**.

(34) The input source **80** starts the power generation and outputs the output voltage V_{in} at a certain timing ($t1$). Here, the output voltage V_{in} is assumed to be constant to simplify the description. After that, the switch activation unit **18** starts boosting the voltage ($t2$), and the switch activation voltage V_{cp} rises. After that, the switch activation voltage V_{cp} is applied to the control terminal **16** of the first transistor **14** ($t3$). In this manner, the first transistor **14** is turned on, the boost operation of the DC-DC converter **90** is started ($t4$), and the boost voltage V_{boost} rises. When the boost voltage V_{boost} rises to a voltage at which a DCDC operation is possible ($t5$), the switch activation unit **18** is turned off and the switch activation voltage V_{cp} becomes 0V. The DCDC operation means that the switch activation unit **18** is turned off, and the MPPT control circuit **22** and the DC-DC control unit **48** are operated by the boost voltage V_{boost} .

(35) Subsequently, the DC-DC converter **90** switches to the DCDC operation. During a period in which the boost voltage V_{boost} is output to the high voltage selector circuit **20**, the MPPT control circuit **22** applies the reference voltage lower than the boost voltage, to the control terminal **26** of the second transistor **24**. In this manner, the MPPT control circuit **22** controls the turning on and the turning off of both of the first transistor **14** and the second transistor **24**. The reference voltage may be 0V. That is, during the period in which the MPPT control circuit **22** outputs the boost voltage V_{boost} to the high voltage selector circuit **20**, at least either one of the first transistor **14** or the

second transistor **24** is in the on state, and the DC-DC converter **90** performs the boost operation. During the period described above, both of the first transistor **14** and the second transistor **24** may be in the on state. In addition, during a period in which the reference voltage is output to the high voltage selector circuit **20**, the MPPT control circuit **22** applies the boost voltage V_{boost} , to the control terminal **26** of the second transistor **24**. In FIG. 2, during a period in which the voltage $N1$ is 0V and the voltage $N2$ is the boost voltage V_{boost} , both of the first transistor **14** and the second transistor **24** are turned off. During this period, the MPPT control circuit **22** measures the output impedance R_{source} of the input source **80**, and the DC-DC control unit **48** adjusts the input impedance of the DC-DC converter **90**. The MPPT control circuit **22** may also measure the open-circuit voltage V_{source} of the input source **80**. That is, the MPPT control circuit **22** may control the first transistor **14** and the second transistor **24** to be in the off state, while the open-circuit voltage V_{source} or the output impedance R_{source} of the input source **80** is measured. The MPPT control circuit **22** may control at least either one of the first transistor **14** or the second transistor **24** to be in the on state, while the DC-DC converter **90** performs the boost operation. Note that the second transistor **24** may not be provided. In that case, the MPPT control circuit **22** controls the turning on and the turning off of the first transistor **14**.

(36) The voltage $N2$ is fixed to the reference voltage until the DCDC operation is started.

Therefore, when the output voltage is sufficiently high, the second transistor **24** is turned on instantly, and the boost operation of the DC-DC converter **90** is started.

(37) When a potential of the boost voltage V_{boost} becomes high to be equal to the output voltage V_{in} at the time of the DCDC operation, the on-resistance of the first transistor **14** which is the N channel MOSFET, becomes high. In that case, when the second transistor **24** is present, the second transistor **24** can be turned on with an on-resistance lower than that of the first transistor **14**.

Therefore, the on-resistance due to the switch can be reduced over a wide range of the output voltages V_{in} .

(38) FIG. 3 is a diagram showing an example of a switch activation unit **18**. The switch activation unit **18** of the present example includes an oscillator circuit **72**, a charge pump **74**, a conversion unit **76**, and a drive unit **78**.

(39) The oscillator circuit **72** is, for example, a ring oscillator. The ring oscillator is a voltage control oscillator that uses the output voltage V_{in} as a control voltage, and outputs an oscillation signal $CLK1$ having a frequency in accordance with the output voltage V_{in} . As the output voltage V_{in} rises, an oscillation frequency may also rise. An amplitude (a wave height value) of the oscillation signal $CLK1$ is the boost voltage V_{in} .

(40) The charge pump **74** boosts the output voltage V_{in} to switch activation voltage V_{cp} . The switch activation voltage V_{cp} is output to the control terminal **16** of the first transistor **14**. The conversion unit **76** outputs a signal $CLK2$ obtained by converting an amplitude V_{in} of the input oscillation signal $CLK1$ into the switch activation voltage V_{cp} .

(41) The drive unit **78** adjusts a pulse width of the signal $CLK2$. The signal $CLK2$ has a pulse width dependent on the output voltage V_{in} in an oscillation operation in the oscillator circuit **72**. The drive unit **78** outputs a signal $CLK3$ whose pulse width is changed from the pulse width dependent on the output voltage V_{in} to a fixed pulse width. The signal $CLK3$ may be input to the control terminal of the boost switch **46**. In this case, the turning on and the turning off of the boost switch **46** is controlled by the frequency, the amplitude, and the pulse width of the signal $CLK3$, and the boost operation of the DC-DC converter **90** is performed.

(42) While the embodiments of the present invention have been described, the technical scope of the invention is not limited to the above described embodiments. It is apparent to persons skilled in the art that various alterations and improvements can be added to the above-described embodiments. It is also apparent from the scope of the claims that the embodiments added with such alterations or improvements can be included in the technical scope of the invention.

EXPLANATION OF REFERENCES

(43) **10** . . . control circuit, **12** . . . input terminal, **14** . . . first transistor, **16** . . . control terminal, **18** . . . switch activation unit, **20** . . . high voltage selector circuit, **22** . . . MPPT control circuit, **24** . . . second transistor, **26** . . . control terminal, **28** . . . source terminal, **40** . . . boost coil, **41** . . . first capacitor, **42** . . . second capacitor, **43** . . . third capacitor, **44** . . . fourth capacitor, **46** . . . boost switch, **48** . . . DC-DC control unit, **52** . . . node, **54** . . . node, **72** . . . oscillator circuit, **74** . . . charge pump, **76** . . . conversion unit, **78** . . . drive unit, **80** . . . input source, **90** . . . DC-DC converter, **100** . . . energy harvesting system.

Claims

1. A control circuit which controls a DC-DC converter which boosts an output voltage of an input source and outputs the output voltage which has been boosted, wherein the DC-DC converter has: a boost coil; and a capacitor, and the control circuit comprises: an input terminal into which the output voltage is input; a first transistor one end of which is coupled to the input terminal and another end of which is coupled to a node between one end of the boost coil and one end of the capacitor; and a switch activation unit which boosts the output voltage, and applies the output voltage, which has been boosted, to a control terminal of the first transistor.
2. The control circuit according to claim 1, further comprising: a high voltage selector circuit which selects a voltage that is applied to the control terminal of the first transistor, wherein the high voltage selector circuit selects whichever is higher of a switch activation voltage boosted by the switch activation unit, and a boost voltage boosted by a boost operation of the DC-DC converter.
3. The control circuit according to claim 2, wherein when the boost voltage rises to a predetermined voltage, the switch activation unit is brought into an off state.
4. The control circuit according to claim 3, further comprising: an MPPT control circuit which outputs the boost voltage to the high voltage selector circuit.
5. The control circuit according to claim 4, wherein the first transistor is an N channel MOSFET, the control circuit has a second transistor which is a P channel MOSFET arranged in parallel with the first transistor, the output voltage is applied to a source terminal of the second transistor, and during a period in which the boost voltage is output to the high voltage selector circuit, the MPPT control circuit applies a reference voltage lower than the boost voltage, to a control terminal of the second transistor.
6. The control circuit according to claim 4, wherein the MPPT control circuit measures an open-circuit voltage or an output impedance of the input source, and the control circuit further comprises a DC-DC control unit which controls an operation of the DC-DC converter based on a measurement result in the MPPT control circuit.
7. The control circuit according to claim 5, wherein the MPPT control circuit measures an open-circuit voltage or an output impedance of the input source, the control circuit further comprises a DC-DC control unit which controls an operation of the DC-DC converter based on a measurement result in the MPPT control circuit, and the MPPT control circuit controls the first transistor to be in an off state, while the open-circuit voltage or the output impedance of the input source is measured, and controls at least either one of the first transistor or the second transistor to be in an on state, while the DC-DC converter performs the boost operation.
8. The control circuit according to claim 1, wherein the first transistor is coupled to a node between the input terminal of the control circuit and an input terminal of the switch activation unit.
9. A DC-DC converter comprising: the control circuit according to claim 1.
10. An energy harvesting system comprising: the DC-DC converter according to claim 9; and the input source which outputs the output voltage to the DC-DC converter.
11. The control circuit according to claim 5, wherein the MPPT control circuit measures an open-circuit voltage or an output impedance of the input source, and the control circuit further comprises a DC-DC control unit which controls an operation of the DC-DC converter based on a

measurement result in the MPPT control circuit.

12. A DC-DC converter comprising: the control circuit according to claim 2.

13. A DC-DC converter comprising: the control circuit according to claim 3.

14. A DC-DC converter comprising: the control circuit according to claim 4.

15. A DC-DC converter comprising: the control circuit according to claim 5.

16. A DC-DC converter comprising: the control circuit according to claim 8.

17. The control circuit according to claim 1, further comprising a boost switch one end of which is coupled to the other end of the boost coil and another end of which is coupled to a ground terminal.

18. A control circuit which controls a DC-DC converter which boosts an output voltage of an input source and outputs the output voltage which has been boosted, wherein the DC-DC converter has: a boost coil; and a capacitor, and the control circuit comprises: an input terminal into which the output voltage is input; a first transistor arranged between the input terminal and the boost coil and the capacitor; and a switch activation unit which boosts the output voltage, and applies the output voltage, which has been boosted, to a control terminal of the first transistor; and a high voltage selector circuit which selects a voltage that is applied to the control terminal of the first transistor, wherein the high voltage selector circuit selects whichever is higher of a switch activation voltage boosted by the switch activation unit, and a boost voltage boosted by a boost operation of the DC-DC converter.
