

Description

The present invention relates to the improvement of direct current-to-direct current (DC—DC) converters.

5 A self-excited DC—DC converter of the prior art is structured by connecting a voltage converting circuit having a feedback loop to a DC power source (dry battery). If the feedback value of the voltage converting circuit is insufficient, this structure will be susceptible to fluctuations in output voltage in response to even slight variations in input voltage. For this reason, a constant-voltage circuit is usually inserted between the dry battery and the voltage converting circuit. The insertion of this constant-voltage circuit, though
10 contributing to the stabilization of the output voltage, has the disadvantage of lowering the conversion efficiency of the converter.

An object of the present invention, therefore, is to provide a DC—DC converter having a high conversion efficiency and a stable output voltage.

Another object of the invention is to provide a DC—DC converter facilitating temperature
15 compensation.

According to the present invention, there is provided a DC—DC converter with feed back self excited switching voltage converting means to provide a DC output and output voltage control circuit means including voltage pick up means connected to the output of the voltage converting means and feedback means for feeding back a voltage dependent on the voltage picked up by the voltage pick up means to the
20 feedback input of the voltage converting means, the feedback means comprising a transistor whose emitter base circuit is connected to the voltage pick up means and whose emitter collector circuit is connected to the feedback input; this DC—DC converter is further characterized in that the voltage pick up means comprises a constant current supply means connected via a resistor to the output of the voltage converting means, the base-emitter circuit of the feedback transistor being connected to the voltage of the constant
25 current supply means so that the output voltage of the converting means is the sum of the voltage drop in the resistor connected in series with the constant current source supply means and the base emitter voltage of the feedback transistor.

Other objects, features and advantages of the present invention will become more apparent from the detailed description hereunder taken in conjunction with the accompanying drawings, wherein:

30 Fig. 1 is a schematic circuit diagram illustrating an example of a DC—DC converter of the prior art;

Figs. 2 and 3 are graphs respectively showing the battery voltage-versus-source current characteristic and the battery voltage-versus-conversion efficiency characteristic of the DC—DC converter shown in Fig. 1;

Fig. 4 is a schematic circuit diagram illustrating an embodiment of a DC—DC converter according to the
35 present invention;

Fig. 5 is a circuit diagram illustrating one example of the voltage converter circuit of the DC—DC converter shown in Fig. 4;

Figs. 6 and 7 are graphs respectively showing the battery voltage-versus-source current characteristic and the battery voltage-versus-conversion efficiency characteristic of the DC—DC converter shown in Fig. 4;
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Fig. 8 is a schematic circuit diagram illustrating another embodiment of a DC—DC converter according to the invention; and

Fig. 9 is a schematic circuit diagram illustrating still another embodiment of a DC—DC converter according to the invention.

45 Referring to Fig. 1, as stated above, a DC—DC converter is composed by connecting in series a constant-voltage circuit 3 and a voltage converter section 5. For instance, while the voltage at an output terminal 2 supplied from a dry battery 1 varies from 1.7 V to 1.0 V, that at a terminal 4 is stabilized at a constant level of 1.0 V by the constant-voltage circuit 3. Afterwards, the voltage at the terminal 4 is boosted by the voltage converter section 5, so that a constant voltage of 2 V can be provided at an output terminal 6.

50 Let us consider a case in which the constant-voltage circuit 3 is not used, or the voltage converter section 5 is directly driven by the dry battery 1. If the voltage $V_{(open)}$ at the output terminal 6, which indicates that the resistance of a feedback resistor 54 is infinitely great, is sufficiently higher than the desired stabilized output voltage $V_{(STB)}$, the feedback voltage determined by the ratio between resistances of resistors 54 and 55 will stabilize $V_{(STB)}$, which is represented by
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$$V_{(STB)} = V_{BE} \left(1 + \frac{R_4}{R_5} \right),$$

60 where R_4 and R_5 are the resistances of the resistors 54 and 55, respectively, and V_{BE} is the base-emitter voltage of a transistor 52. If

$$\frac{V_{(open)}}{V_{(STB)}}$$

is only about 1.8, no sufficient feedback can be achieved, so that fluctuations in input voltage to the terminal 4 would invite variations in output voltage at the output terminal 6.

If the constant-voltage circuit 3 is added to such a circuit, the source current, as seen in the graph of Fig. 2, will remain substantially constant at I_1 regardless of fluctuations in the voltage from the dry battery 1.

5 The conversion efficiency η_1 in this case, as shown in the graph of Fig. 3, is represented by

$$\eta_1 = \frac{I_L V_L}{I_1 V_{B1}} \quad (1)$$

10 where I_L and V_L are the current and voltage, respectively, of the load and V_{B1} is the battery voltage. I_L , V_L and I_1 are constant values under a quiescent condition. Therefore, the DC—DC converter of Fig. 1, as shown in Fig. 3, has the disadvantage that the efficiency η_1 declines with a rise in the voltage V_{B1} of the dry battery 1.

15 Detailed description of the preferred embodiments

Referring now to Fig. 4, a DC—DC converter according to the present invention comprises a dry battery 11, a switch 12, a self-excited type switching voltage converter 16 to which an input voltage is fed via the switch 12, an output-voltage control circuit 17 connected to the output side of the switching voltage converter 16, and a resistor 13 connected between an input terminal 14 and a control input terminal 15 of the switching voltage converter 16. The output-voltage control circuit 17 stabilizes the output of the switching voltage converter 16 to provide a constant voltage output at the terminals 18 and 19. The control circuit 17 includes resistors 171 and 172 and a transistor 174, all connected between output terminals 18 and 19 of the switching voltage converter 16, a transistor 175 whose base is connected to the collector of the transistor 174, and a resistor 173 connected to the collector of the transistor 175. The resistors 171 and 172 and transistors 174 and 175 constitute a constant current supply circuit, which will be described later. The output-voltage control circuit 17 further includes a transistor 176 for providing a feedback signal to the feedback input 15 of the switching voltage converter 16. The feedback signal is picked up by a voltage picking-up element, i.e., the resistor 173. The base of transistor 176 is connected to the collector of transistor 175 and the collector of transistor 176 is connected to the feedback input terminal 15.

20 The switching voltage converter 16 is composed as illustrated in Fig. 5. As the switch 12 is turned on, a voltage from the dry battery 11 is fed to the input terminal 14 to let oscillation start automatically, and a high voltage is generated on the output side of a boosting coil 162. The voltage so generated is rectified by a diode 163 and a capacitor 164, and is taken out as a high, boosted DC voltage between the output terminals 18 and 19.

25 Again referring to the output-voltage control circuit 17 as illustrated in Fig. 4, the output voltage V_{out} between the output terminals 18 and 19 is represented by

$$\begin{aligned} V_{out} &= VF_1 + I_{c1} \cdot R_1 = VF_1 + \frac{R_1}{R_2} (VF_1 - VF_2) \\ &= VF_3 + I_{c2} \cdot R_3 \end{aligned} \quad (2)$$

30 where R_1 is the resistance of the resistor 171, R_2 is that of the resistor 172, R_3 is that of the resistor 173, VF_1 is the base-emitter voltage of the transistor 174, I_{c1} is the collector current of same, VF_2 is the base-emitter voltage of the transistor 175, I_{c2} is the collector current of same, and VF_3 is the base-emitter voltage of the transistor 176. Therefore, by selecting the resistances R_1 , R_2 and R_3 , the base-emitter voltages VF_1 , VF_2 and VF_3 and the collector currents I_{c1} and I_{c2} are determined, and it is thereby made possible to set the output voltage V_{out} at any desired level.

Further, by selecting

$$R_2 \approx \frac{26 \text{ mV}}{I_{c1}} \quad (3)$$

35 for the resistance R_2 of the resistor 172, the collector current I_{c2} of the transistor 175 can be made constant, because the collector voltage of transistor 174 remains unchanged even if the collector current I_{c1} of the transistor 174 varies as a result of a fluctuation in the voltage at the output terminal 18. Therefore, it is only necessary to select the resistance R_3 of the resistor 173 so as to set the output voltage V_{out} at any desired level according to Equation (2) above. Incidentally, the value of 26 mV in Equation (3) is calculated by the use of KT/q , where K is Boltzmann's constant, T is an absolute temprature, and q is an electric charge.

40 Since the circuit component constants are selected in this manner to let a feedback signal be supplied from the collector of the transistor 175 to the base of the transistor 176, the oscillation frequency of the switching voltage converter 16 is controlled by the output signal of the transistor 176, and a stabilized, converted voltage is provided at the output terminals 18 and 19. Thus, it is seen that this converted voltage is determined by the resistances R_1 , R_2 and R_3 of the resistors 171, 172 and 173, respectively, but not affected by any voltage fluctuation of the dry battery 11. In this way, the stabilization of the output voltage is

unaffected unlike in the prior art because, even if the feedback by the transistor 176 drops, the output voltage is determined by the relationship of Equation (2) above. Further, if the voltage supplied from the dry battery rises, the voltage boost (the ratio of the converted voltage to the battery voltage) will correspondingly decrease, resulting in the advantage of a saving in current consumption.

The graphs of Figs. 6 and 7 show the variation characteristics of the source current and conversion efficiency, respectively, relative to battery voltage fluctuations, attained with the embodiment of Fig. 4. As these graphs indicate, the source current I_s declines with a rise in battery voltage V_{B1} , so that the efficiency η remains constant irrespective of the battery voltage V_{B1} . When the battery voltage V_{B1} is 1.4 V, for instance, a 30% improvement will be achieved over the efficiency η_1 of the conventional circuit. This embodiment makes it possible to keep the voltage fluctuation rate relative to the input voltage at about 3%/V when the fluctuation range of the battery voltage is from 1.0 to 1.7 V and the stabilized output voltage is set at 2.0 V, which means an improvement by about 1/2.6 over the approximately 8%/V rate of the conventional circuit.

Fig. 8 is a circuit diagram illustrating a second preferred embodiment of the present invention. This embodiment differs from the first embodiment in that the PNP type transistors 244 to 246 are used instead of the NPN type transistors 174 and 176 in the first embodiment shown in Fig. 4 and in that, in connection with that change, the voltage on the negative side is stabilized with reference to the battery voltage. However, the second embodiment is no different from the first one in any other respect either in structure or in operation. In Fig. 8, reference numeral 24 denotes an output voltage control circuit, and 23, a switching voltage converter.

Fig. 9 is a circuit diagram illustrating a third preferred embodiment of the present invention. This circuit differs from the first embodiment in that a transistor 347 having a diode characteristic is connected in series to a resistor 173 as the collector load of a transistor 175. But, the third embodiment is no different from the first one in any other respect either in structure or in operation. The insertion of the transistor 347 is intended to suppress the fluctuations of the output voltage resulting from changes in ambient temperature. Thus, the current change of the transistor 347 due to temperature changes compensates for the fluctuations in the output voltage of the converter circuit which result from the temperature changes.

Though a diode-connected transistor is used for temperature compensation in this embodiment, the invention is not limited to this embodiment, but obviously a diode or a thermistor having a desirable temperature characteristic for the compensatory purpose can be used as well, or more than one such unit can be employed.

As is evident from the foregoing description, in the DC—DC converter according to the present invention, an output-voltage control circuit is connected to the output side of a voltage converter circuit, which is controlled by this output-voltage control circuit. Therefore, not only can a stabilized, boosted voltage be provided even if the feedback value to the voltage converter circuit is small, but also the conversion efficiency can be kept constant within the fluctuation range of the battery voltage. Furthermore, temperature compensation can be readily achieved merely by connecting in series a diode or the like to the collector load resistance.

Claims

1. A DC—DC converter comprising:

feedback self excited switching voltage converting means (16) to provide a DC output and output voltage control circuit means (17) including voltage pick up means (175, 245, 173) connected to the output (18, 19) of said voltage converting means (16) and feedback means (176, 246, 15) for feeding back a voltage dependent on the voltage picked up by said voltage pick up means (173, 175, 245) to the feedback input (15) of said voltage converting means (16), said feedback means comprising a transistor (176, 246) whose emitter base circuit is connected to said voltage pick up means and whose emitter collector circuit is connected to said input (15) characterised in that the voltage pick up means comprises a constant current supply means (171, 172, 174, 244, 175, 245) connected via a resistor (173) to the output of said voltage converting means (16), the base-emitter circuit of the feedback transistor (176, 246) being connected to the voltage of the constant current supply means so that the output voltage of the converting means (V_{OUT}) is the sum of the voltage drop ($R_1 I_{E2}$) in the resistor (173) connected in series with the constant current source supply means and the base emitter voltage (V_{F3}) of the feedback transistor (176, 246).

2. A DC—DC converter, as claimed in Claim 1, wherein said constant current supply means comprises a first resistor (171) one terminal of which is connected to one of the output terminals (18, 19) of said voltage converting means (16); a first transistor (174, 244) whose base and emitter are respectively connected to the other terminal of said first resistor (171) and the other output terminal (19, 18) of said voltage converting means (16); a second resistor (172) connected between the base and collector of said first transistor (174, 244); and a second transistor (175, 245) whose base, collector and emitter are respectively connected to the collector of said first transistor (174, 244), one terminal of said voltage picking-up means and the other output terminal (19, 18) of said voltage converting means (16).

3. A DC—DC converter as claimed in Claim 1 or 2, further comprising a temperature compensating element (347) connected in series to said voltage picking-up means (173).

4. A DC—DC converter as claimed in Claim 3, wherein said element comprises a diode-connected

unaffected unlike in the prior art because, even if the feedback by the transistor 176 drops, the output voltage is determined by the relationship of Equation (2) above. Further, if the voltage supplied from the dry battery rises, the voltage boost (the ratio of the converted voltage to the battery voltage) will correspondingly decrease, resulting in the advantage of a saving in current consumption.

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Fig. 8 is a circuit diagram illustrating a second preferred embodiment of the present invention. This embodiment differs from the first embodiment in that the PNP type transistors 244 to 246 are used instead of the NPN type transistors 174 and 176 in the first embodiment shown in Fig. 4 and in that, in connection with that change, the voltage on the negative side is stabilized with reference to the battery voltage. However, the second embodiment is no different from the first one in any other respect either in structure or in operation. In Fig. 8, reference numeral 24 denotes an output voltage control circuit, and 23, a switching voltage converter.

Fig. 9 is a circuit diagram illustrating a third preferred embodiment of the present invention. This circuit differs from the first embodiment in that a transistor 347 having a diode characteristic is connected in series to a resistor 173 as the collector load of a transistor 175. But, the third embodiment is no different from the first one in any other respect either in structure or in operation. The insertion of the transistor 347 is intended to suppress the fluctuations of the output voltage resulting from changes in ambient temperature. Thus, the current change of the transistor 347 due to temperature changes compensates for the fluctuations in the output voltage of the converter circuit which result from the temperature changes.

Though a diode-connected transistor is used for temperature compensation in this embodiment, the invention is not limited to this embodiment, but obviously a diode or a thermistor having a desirable temperature characteristic for the compensatory purpose can be used as well, or more than one such unit can be employed.

As is evident from the foregoing description, in the DC—DC converter according to the present invention, an output-voltage control circuit is connected to the output side of a voltage converter circuit, which is controlled by this output-voltage control circuit. Therefore, not only can a stabilized, boosted voltage be provided even if the feedback value to the voltage converter circuit is small, but also the conversion efficiency can be kept constant within the fluctuation range of the battery voltage. Furthermore, temperature compensation can be readily achieved merely by connecting in series a diode or the like to the collector load resistance.

Claims

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2. A DC—DC converter, as claimed in Claim 1, wherein said constant current supply means comprises a first resistor (171) one terminal of which is connected to one of the output terminals (18, 19) of said voltage converting means (16); a first transistor (174, 244) whose base and emitter are respectively connected to the other terminal of said first resistor (171) and the other output terminal (19, 18) of said voltage converting means (16); a second resistor (172) connected between the base and collector of said first transistor (174, 144); and a second transistor (175, 245) whose base, collector and emitter are respectively connected to the collector of said first transistor (174, 244), one terminal of said voltage picking-up means and the other output terminal (19, 18) of said voltage converting means (16).

3. A DC—DC converter as claimed in Claim 1 or 2, further comprising a temperature compensating element (347) connected in series to said voltage picking-up means (173).

4. A DC—DC converter as claimed in Claim 3, wherein said element comprises a diode-connected



transistor (347).

Patentansprüche

- 5 1. Gleichstrom-Gleichstrom-Wandler mit einem rückgekoppelten, selbsterregten Schaltspannungswandler (16) zum Erzeugen eines Gleichstroms und mit einer Ausgangsspannungs-Steuerschaltung (17) mit einem Spannungsaufnehmer (175, 245, 173), der mit dem Ausgang (18, 19) des Spannungswandlers (16) verbunden ist, und einer Rückkoppeleinrichtung (176, 246, 15) zum Rückkoppeln einer Spannung, die von der vom Spannungsaufnehmer (173, 175, 245) aufgenommenen
10 Spannung abhängt, zum Rückkoppeleingang (15) des Spannungswandlers (16), wobei die Rückkoppeleinrichtung einen Transistor (176, 246) aufweist, dessen Emitter-Basis-Kreis mit dem Spannungsaufnehmer und dessen Emitter-Kollektor-Kreis mit dem Eingang (15) verbunden ist, dadurch gekennzeichnet, daß der Spannungsaufnehmer eine Konstantstromquelle (171, 172, 174, 244, 175, 245) aufweist, die über einen Widerstand (173) mit dem Ausgang des Spannungswandlers (16) verbunden ist,
15 daß der Basis-Emitter-Kreis des Rückkoppeltransistors (176, 246) mit der Spannung der Konstantstromquelle derart verbunden ist, daß die Ausgangsspannung (V_{OUT}) des Wandlers gleich der Summe des Spannungsabfalls ($R_3 I_{c2}$) im Widerstand (173), der in Reihe mit der Konstantstromquelle geschaltet ist, und der Basis-Emitter-Spannung (V_{F3}) des Rückkoppeltransistors (176, 246) ist.
2. Gleichstrom-Gleichstrom-Wandler nach Anspruch 1, dadurch gekennzeichnet, daß die
20 Konstantstromquelle einen ersten Widerstand (171), dessen einer Anschluß mit einem Ausgangsanschluß (18, 19) des Spannungswandlers (16) verbunden ist, einen ersten Transistor (174, 244), dessen Basis und Emitter mit dem anderen Anschluß des ersten Widerstandes (171) bzw. dem anderen Ausgangsanschluß (19, 18) des Spannungswandlers (16) verbunden ist, einen zweiten Widerstand (172), der zwischen Basis und Kollektor des ersten Transistors (174, 144) geschaltet ist, und einen zweiten Transistor (175, 245)
25 aufweist, dessen Basis, Kollektor und Emitter mit dem Kollektor des ersten Transistors (174, 244), einem Anschluß des Spannungsaufnehmers bzw. dem anderen Ausgangsanschluß (19, 18) des Spannungswandlers (16) verbunden sind.
3. Gleichstrom-Gleichstrom-Wandler nach Anspruch 1 oder 2, gekennzeichnet durch einen Temperaturkompensator (347), der in Reihe mit dem Spannungsaufnehmer (173) geschaltet ist.
- 30 4. Gleichstrom-Gleichstrom-Wandler nach Anspruch 3, dadurch gekennzeichnet, daß der Temperaturkompensator einen als Diode geschalteten Transistor (347) aufweist.

Revendications

- 35 1. Convertisseur continu-continu comprenant:
un moyen de conversion de tension de commutation auto-excitée à réaction (16) afin de fournir une sortie à courant continu et
un moyen (17) de circuit de commande de tension de sortie comportant un moyen de captage de tension (175, 245, 173) connecté à la sortie (18, 19) du moyen de conversion de tension (16) et un moyen de
40 réaction (176, 246, 15) pour renvoyer une tension dépendant de la tension captée par le moyen de captage de tension (173, 175, 245) à l'entrée de réaction (15) du moyen de conversion de tension (16), le moyen de réaction comportant un transistor (176, 246) dont le circuit émetteur-base est connecté au moyen de captage de tension et dont le circuit émetteur-collecteur est connecté à l'entrée (15), caractérisé en ce que:
le moyen de captage de tension comprend un moyen d'alimentation à courant constant (171, 172, 174,
45 244, 175, 245) connecté via une résistance (173) à la sortie du moyen de conversion de tension (16), le circuit base-émetteur du transistor de réaction (176, 246) étant connecté à la tension du moyen d'alimentation à courant constant de sorte que la tension de sortie du moyen de conversion (V_{OUT}) est la somme de la chute de tension ($R_3 I_{c2}$) dans la résistance (173) connectée en série au moyen d'alimentation à courant constant et la tension base-émetteur (V_{F3}) du transistor de réaction (176, 246).
- 50 2. Convertisseur continu-continu selon la revendication 1, dans lequel le moyen d'alimentation à courant constant comprend une première résistance (171) dont une borne est connectée à l'une des bornes de sortie (18, 19) du moyen de conversion de tension (16); un premier transistor (174, 244) dont la base et l'émetteur sont respectivement connectés à l'autre borne de la première résistance (171) et à l'autre borne de sortie (19, 18) du moyen de conversion de tension (16); une seconde résistance (172) connectée entre la
55 base et le collecteur du premier transistor (174, 144); et un second transistor (175, 245) dont la base, le collecteur et l'émetteur sont respectivement connectés au collecteur du premier transistor (174, 244) à une borne du moyen de captage de tension et à l'autre borne de sortie (19, 18) du moyen de conversion de tension (16).
3. Convertisseur continu-continu selon la revendication 1 ou la revendication 2, comprenant en outre
60 un élément de compensation de température (347) connecté en série au moyen (173) de captage de tension.
4. Convertisseur continu-continu selon la revendication 3, caractérisé en ce que l'élément comprend un transistor (347) connecté en diode.

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