

**UNIPOLAR OR BIPOLAR CHOPPING CONVERTER WITH TWO
MAGNETICALLY COUPLED WINDINGS**

DESCRIPTION

TECHNICAL FIELD

The invention relates to a unipolar or
5 bipolar chopping converter, operating in the quadrants
($I_s > 0$; $V_s > 0$) and ($I_s < 0$; $V_s < 0$), and with zero output
current or voltage, having magnetically coupled
windings, which may be configured with the regulation
mode adapted in current source or voltage source. It
10 applies to all types of terrestrial, naval or aerial
equipment using this type of chopping converter,
particularly the electromechanical actuator controls of
regulating automatons for turbine engines.

15 **STATE OF THE PRIOR ART**

The control of electrical actuators with an
RL type load (resistor and inductance in series) may be
achieved either by application of a regulated voltage
at the terminals of the control coil of the actuator,
20 or by a current source, this latter solution often
being preferred in severe environments essentially
because it enables the power used to control the
accessory to be limited.

Chopping current sources may conventionally
25 be grouped together among current sources using the
inductance of the load as energy storage element during
the chopping operation, with as consequence the
application at the terminals of the load, at the

chopping frequency, of an alternatively positive and negative voltage, the transitions between these two states ideally being considered as instantaneous, and current sources supplying a continuous current and, consequently, a continuous voltage at the terminals of the load, in which the energy storage element for the chopping is situated on the control card itself.

Chopping current sources using the inductance of the load as energy storage element have the advantage of having a control that is, at first sight, simple. They comprise few or possibly no inductive elements, which leads to a certain saving in the dimensions of the circuit. On the other hand, they have a certain number of disadvantages. They have a high dependency vis-à-vis the value of the inductance of the load: the capability of controlling the instantaneous current in the switches of the current source depends directly on the charge inductance value. The resistance to short circuits between the output terminals of the converter or between any output terminal and earth is very difficult. Indeed, in the event of short circuit of the load, it is not possible, except by adding components, to limit the instantaneous current. Consequently, in practice it is necessary to add an inductance at the output of the converter in order to limit the short circuit current, to add a protection and very rapid cut off device to limit the maximum value of the short circuit current, to add a circuit for demagnetising the output inductance to manage the cut off after the detection of the short circuit at the output, to over-dimension the interfaces

(input filtering capacitor) so that they can withstand the short circuit current. Concerning the electromagnetic compatibility aspect (conducted emissions essentially), these converters are difficult to render compatible with aeronautic emission standards, if a high chopping frequency is desired to limit the size of the passive components of the converters, especially if the load is controlled at the end of several metres of cable. The result is a chopping frequency reduced typically to below 10 kHz and an obligation to dimension an output filter (shared mode and differential mode) that will play a prominent role in the stability of the assembly and will have a non negligible size. This type of chopping current source is restricted to high power applications, for which a low chopping frequency is not necessarily a handicap.

For converters supplying a continuous voltage at the terminals of the load, the chopping no longer takes place in the load but the current (or the voltage) is regulated at the output of a chopping converter comprising an inductance storing at least all of the energy transferred to the load and a capacitor is added to smooth out the output voltage. Consequently, the output voltage is virtually continuous at the terminals of the load. There is therefore less difficulty in meeting aeronautic standards for noise emitted in conduction. In the event of short circuit of the load, the current in the converter remains naturally limited. Chopping frequencies exceeding 100 kHz may be envisaged, limited

in fact by the efficiency of the converter and the performance of the gate control circuits of switch elements.

Figure 1a is an electrical diagram of a converter of the prior art supplying a continuous voltage at the terminals of a load. The circuit is supplied by a positive voltage V_p (for example +25V) and a negative voltage V_m (for example -25V) with respect to earth. It comprises two elements T1 and T2 each comprising two windings magnetically coupled around a magnetic core. The windings of a same element T1 or T2 are wound in opposition as indicated by a point in figure 1a. The winding E1 of the element T1 has a first end connected to the voltage V_p through the intermediary of a diode D5 inversely mounted in relation to the voltage V_p , its second end being to earth. The winding E2 of the element T1 has a first end connected to a first terminal of a switch Q3 in which the second terminal is connected to the voltage V_p . The second end of the winding E2 is connected to the output terminal S1P of the circuit. The winding E3 of the element T2 has a first end connected to the voltage V_m through the intermediary of a diode D6 inversely mounted in relation to the voltage V_m , its second end being to earth. The winding E4 of the element T2 has a first end connected to a first terminal of a switch Q4 in which the second terminal is connected to the voltage V_m . The second end of the winding E4 is connected to the output terminal S1P of the circuit. A smoothing capacitor C1 is connected between the output S1P and the earth.

The converter is transformed into current source by the addition of means of measuring the output current, a suitable regulation and modulator. This is shown in figure 1b where the load connected to the output of the converter is represented in the form of a resistor R_c and an inductance L_c connected in series. The output current is measured by a measuring means 1 that delivers a representative signal to a first input of a regulation means (or equaliser) 2. A second input E_c of the regulation means 2 receives a set point signal. The output signal of the regulation means 2 is addressed to the input of a modulator 3 that delivers a command signal SQ_3 to the switch Q_3 and a command signal SQ_4 to the switch Q_4 .

The converter illustrated in figure 1a comprises therefore four windings and two magnetic cores, which leads to a relatively high cost and a relatively large size of the circuit.

20 DESCRIPTION OF THE INVENTION

In order to reduce the cost and the size of a chopping converter supplying a continuous positive, negative or zero voltage at the terminals of a load, a circuit with two windings coupled on a single magnetic core is proposed, according to the present invention. It is then necessary to add two diodes to the circuit, but these elements are of low cost and of low size.

A first subject of the invention consists in a chopping converter supplied by a positive voltage and a negative voltage with respect to earth, and delivering an output voltage between a first output

terminal and a second output terminal, comprising two windings wound in opposition around a magnetic core, the number of turns of the second winding being greater than the number of turns of the first winding, the
5 first end of the first winding being connected to a mid point of a first branch connecting the positive voltage to the negative voltage and comprising a first diode and a second diode inversely mounted, the mid point of the first branch being situated between the first diode
10 and the second diode, the second end of the first winding being connected to earth, the first end of the second winding being connected to a mid point of a second branch connecting the positive voltage to the negative voltage, the part of the second branch
15 connecting its mid point to the positive voltage comprising, arranged in series, a first switch forming means and a third diode directly mounted in relation to the positive voltage and together forming a unidirectional switch with direct and inverse blocking
20 capability, the part of the second branch connecting its mid point to the negative voltage comprising, arranged in series, a second switch forming means and a fourth diode directly mounted in relation to the negative voltage and together forming a unidirectional
25 switch with direct and inverse blocking capability, the second end of the second winding being connected to the output terminal.

Advantageously, a smoothing capacitor is connected between the first output terminal of the
30 converter and earth.

Also advantageously, in the second branch connecting the positive voltage to the negative voltage, said arrangement in series consists in arranging the first and second switch forming means on
5 the side of the respective positive or negative voltages and arranging the third and fourth diodes on the side of the mid point of the second branch.

The switch forming means may be chosen among MOS transistors, bipolar transistors and IGBT
10 transistors or any other switch having a bidirectional conduction capability and a direct blocking capability.

The converter may further comprise a means of measuring the output voltage of the converter, said measuring means delivering an output signal
15 representative of the output voltage to a first input of a regulation means in which a second input receives a set point signal, the regulation means delivering a signal supplied to the input of a modulator in which a first output sends a command signal to the first switch
20 forming means and in which a second output sends a command signal to the second switch forming means, the converter being thereby configured in voltage source.

The converter may further comprise a means of measuring the output current (is) of the converter, said measuring means delivering an output signal
25 representative of the output current of the converter to a first input of a regulation means in which a second input receives a set point signal, the regulation means delivering a signal supplied to the input of a modulator in which a first output sends a
30 command signal to the first switch forming means and in

which a second output sends a command signal to the second switch forming means, the converter being configured in current source.

The chopping converter according to the invention may equip an electromechanical actuator control, a regulating automaton, a turbine engine or terrestrial, naval or aeronautic equipment.

The chopping converter according to the present invention may operate according to the following methods.

A first method comprises the following steps, for an operating cycle and to pass a negative current in the load:

- a first step during which a first switch forming means are open, the fourth diode is conducting, the second switch forming means are closed and the first, second and third diodes are blocked during a first part of the cycle, the converter operating in continuous mode or in discontinuous mode,

- a second step, following the first step, during which, the first and second switch forming means are open, the second diode is conducting and the first, third and fourth diodes are blocked during a second part of the cycle, this second part of the cycle not ending the cycle if the converter operates in discontinuous mode and ending the cycle if the converter operates in continuous mode,

- a third step, following the second step if the converter operates in discontinuous mode, during which the first and second switch forming means are open and the first, second, third and fourth diodes are

blocked during a third part of the cycle ending at the end of the cycle.

A second method comprises the following steps, for an operating cycle and to pass a positive
5 current in the load:

- a first step during which a first switch forming means are closed, the third diode is conducting, the second switch forming means are open and the first, second and fourth diodes are blocked
10 during a first part of the cycle, the converter operating in continuous mode or in discontinuous mode,

- a second step, following the first step, during which the first diode is conducting, the first and second switch forming means are open and the
15 second, third and fourth diodes are blocked during a second part of the cycle, this second part of the cycle not ending the cycle if the converter operates in discontinuous mode and ending the cycle if the converter operates in continuous mode,

- a third step, following the second step if the converter operates in discontinuous mode, during which the first and second switch forming means are open, the first, second, third and fourth diodes are blocked, during a third part of the cycle ending at the
20 end of the cycle.
25

A third method comprises the following steps, for an operating cycle and to pass a negative current in the load, the converter operating in continuous mode:

30 - a first step during which a first switch forming means are closed, the third diode is

conducting, the second switch forming means are open and the first and fourth diodes are blocked, the second diode being blocked if the voltage at the first output with respect to earth is, in absolute value,
5 sufficiently low, during a first part of the cycle,

- a second step, following the first step, during which the first diode is conducting, the first and second switch forming means are open and the second, third and fourth diodes are blocked during a
10 second part of the cycle,

- a third step, following the second step, during which the second switch forming means are closed, the fourth diode is conducting, a first switch forming means are open and the first, second and third
15 diodes are blocked, during a third part of the cycle,

- a fourth step, following the third step, during which the second diode is conducting, the first and second switch forming means are open and the first, third and fourth diodes are blocked, during a fourth
20 part of the cycle ending at the end of the cycle.

A fourth method comprises the following steps, for an operating cycle and to pass a positive current in the load, the converter operating in continuous mode:

25 - a first step during which a first switch forming means are closed, the third diode is conducting, the second switch forming means are open and the first, second and fourth diodes are blocked during a first part of the cycle,

30 - a second step, following the first step, during which the first diode is conducting, the first

and second switch forming means are open and the second, third and fourth diodes are blocked during a second part of the cycle,

- a third step, following the second step,
5 during which the second switch forming means are closed, the fourth diode is conducting, a first switch forming means are open and the second and third diodes are blocked, the first diode is blocked if the voltage at the first output with respect to earth is, in
10 absolute value, sufficiently low, during a third part of the cycle,

- a fourth step, following the third step, during which the second diode is conducting, the first and second switch forming means are open and the first,
15 third and fourth diodes are blocked, during a fourth part of the cycle ending at the end of the cycle.

BRIEF DESCRIPTION OF DRAWINGS

The present invention may best be
20 understood and other advantages and particularities will become apparent by reference to the following description, provided as an indication only and in no way limiting and by referring to the accompanying drawings in which:

25 - figure 1a is an electrical diagram of a chopping converter of the prior art supplying a continuous voltage at the terminals of a load,

- figure 1b is an electrical diagram of the converter of figure 1a used as chopping current source
30 by addition of means of measuring the output current, as well as suitable equaliser and modulator,

- figure 2 is an electrical diagram of a chopping converter supplying a continuous voltage at the terminals of a load and that has led to the development of the present invention,

5 - figure 3 is an electrical diagram of a chopping converter supplying a continuous voltage at the terminals of a load, according to the invention,

- figures 4A to 4N illustrate the operating mode of the present invention,

10 - figures 5A to 5F are chronograms corresponding to different operating modes illustrated by figures 4A to 4N,

- figure 6a shows the principle of using the converter according to the invention as voltage
15 source,

- figure 6b shows the principle of using the converter according to the invention as current source.

20 **DETAILED DESCRIPTION OF AN EMBODIMENT OF THE INVENTION**

Figure 2 is an electrical diagram of a chopping converter supplying a continuous voltage at the terminals of a load, and that has led to the development of the present invention. This converter
25 may be, in the same way as for the converter described in figures 1a and 1b, converted into chopping current source by the addition of a means (direct or indirect) of measuring the current of the load and suitable equaliser and modulator. As for figure 1a, the circuit
30 is supplied by a positive voltage V_p (for example +25V) and a negative voltage V_m (for example -25V) with

respect to earth. It comprises a transformer forming element and comprising three windings L_p , L_{s1} and L_{s2} wound around a unique magnetic core. The winding direction is indicated by a point in figure 2. The windings L_{s1} and L_{s2} are mounted in series to constitute the secondary of the transformer forming element, their shared point (their first ends) being to earth. The winding L_p constitutes the primary of the transformer forming element. The second end of the winding L_{s1} is connected to the voltage V_p through the intermediary of a diode $D1$ inversely mounted in relation to the voltage V_p . The second end of the winding L_{s2} is connected to the voltage V_m through the intermediary of a diode $D2$ inversely mounted in relation to the voltage V_m . The winding L_p has a first end connected to the cathode of a diode $D3$ and to the anode of a diode $D4$. The second end of the winding L_p is connected to the output terminal SP of the circuit. A first terminal of a switch $Q1$ is connected to the anode of the diode $D3$ and its second terminal is connected to the voltage V_p . A first terminal of a switch $Q2$ is connected to the cathode of the diode $D4$ and its second terminal is connected to the voltage V_m . A smoothing capacitor C_s is connected between the output SP and earth. The output SM may be connected to mechanical earth directly, or via a resistor, depending on the needs of the user.

The switches $Q1$ and $Q2$ are advantageously N-channel or P-channel MOSFET transistor elements, depending on the needs of the user. They may be

replaced by any other switch having a bi-directional conduction capability and a direct blocking capability.

N_p being the number of turns of the winding L_p , N_{s1} being the number of turns of the winding L_{s1} and N_{s2} being the number of turns of the winding L_{s2} , N_p is greater than N_{s1} and N_{s2} , for example $N_{s1} = N_{s2} = 0.75 N_p$.

Figure 2 mentions the following voltages:

- v_{q1} at the terminals of Q_1 ,
- v_{q2} at the terminals of Q_2 ,
- v_{d1} at the terminals of D_1 ,
- v_{d2} at the terminals of D_2 ,
- v_{d3} at the terminals of D_3 ,
- v_{d4} at the terminals of D_4 ,
- v_{ls1} at the terminals of L_{s1} ,
- v_{ls2} at the terminals of L_{s2} ,
- v_{lp} at the terminals of L_p , and
- v_s at the terminals of C_s , i.e. the output voltage of the converter.

Figure 2 also mentions the following currents:

- i_{ls1} flowing through the winding L_{s1} ,
- i_{ls2} flowing through the winding L_{s2} ,
- i_{lp} flowing through the winding L_p , and
- i_s flowing through the load Z of the converter, i.e. the output current.

The current source of figure 2 has a certain advantage compared to the current source of the prior art illustrated in figure 1a. A reading of measurements carried out on an assembly such as shown in figure 2 has made it possible to observe that, in an

unexpected manner, the anode of the diode D1 and the cathode of the diode D2 were always at the same potential. These two points have therefore been electrically connected and one of the secondary windings has been deleted. This is shown in figure 3 where the remaining secondary winding is known as L_s , its number of turns is such that N_s is less than the number of turns N_p of the primary winding L_p . Figure 3 shows a load Z connected at the output of the converter.

The operation of the chopping converter will now be explained in reference to figures 4A to 4N as a function of the commands (closing, opening) sent to the switches Q1 and Q2. In these figures, the currents that flow in the circuit are indicated by bold lines. As will be seen, the converter according to the invention is a two quadrant converter:

$$(v_s > 0, i_s > 0) \text{ and } (v_s < 0, i_s < 0).$$

Figures 4A to 4F concern an operating mode where a single transistor Q1 or Q2 (forming switch) conducts when the output current is positive ($i_s > 0$) or when the output current is negative ($i_s < 0$).

Figures 4A to 4C concern an operating mode where the output current " i_s " is negative, for an operating cycle (from $t=0$ to $t=T$).

Figure 4A illustrates a first step of the operating cycle between the instants $t=0$ and $t=t_1$ (where $t_1 < T$). The circuit may operate in continuous mode and in discontinuous mode. During this step, the command of the circuit is such that:

- Q2 and D4 conduct,

- Q1, D1, D2 and D3 are blocked.

Figure 4B illustrates a second step of the operating cycle, between the instants $t=t_1$ and $t=t_2$. The circuit may operate in continuous mode (in this case
 5 $t_2=T$) or in discontinuous mode. During this step, the command of the circuit is such that:

- D2 conducts,
- Q1, Q2, D1, D3 and D4 are blocked.

Figure 4C illustrates a third step of the
 10 operating cycle, uniquely for the discontinuous mode, between $t=t_2$ and $t=T$. During this step, the command of the circuit is such that:

- Q1, Q2, D1, D2, D3 and D4 are blocked,
- the current "is" flowing in the load is
 15 supplied by the energy accumulated in the capacitor Cs.

Figure 5A shows the chronograms corresponding to the operating mode illustrated by figures 4A to 4C for a discontinuous mode, therefore for an operating cycle comprising three steps.

20 Figure 5B shows the chronograms corresponding to the operating mode illustrated by figures 4A and 4B for a continuous mode, therefore an operating cycle comprising two steps.

Figures 4D to 4F concern an operating mode
 25 where the output current "is" is positive, for an operating cycle (from $t=0$ to $t=T$).

Figure 4D illustrates a first step of the operating cycle between the instants $t=0$ and $t=t_1$ (where $t_1<T$). The circuit may operate in continuous
 30 mode and in discontinuous mode. During this step, the command of the circuit is such that:

- Q1 and D3 conduct,
- Q2, D1, D2 and D4 are blocked.

Figure 4E illustrates a second step of the operating cycle, between the instants $t=t_1$ and $t=t_2$. The circuit may operate in continuous mode (in this case $t_2=T$) or in discontinuous mode. During this step, the command of the circuit is such that:

- D1 conducts,
- Q1, Q2, D2, D3 and D4 are blocked.

Figure 4F illustrates a third step of the operating cycle, uniquely for the discontinuous mode, between $t=t_2$ and $t=T$. During this step, the command of the circuit is such that:

- Q1, Q2, D1, D2, D3 and D4 are blocked,
- the current "is" flowing in the load is supplied by the energy accumulated in the capacitor Cs.

Figure 5C shows the chronograms corresponding to the operating mode illustrated by figures 4D to 4F for a discontinuous mode, therefore for an operating cycle comprising three steps.

Figure 5D shows the chronograms corresponding to the operating mode illustrated by figures 4D and 4E for a continuous mode, therefore for an operating cycle comprising two steps.

Figures 4G to 4N concern an operating mode where the two transistors Q1 and Q2 (forming switch) conduct when the output current is negative ($i_s < 0$) and when the output current is positive ($i_s > 0$). The operation described is in continuous mode.

Figures 4G to 4J concern an operating mode where the output current "is" is negative, for an operating cycle (from $t=0$ to $t=T$).

Figure 4G illustrates a first step of the operating cycle, between the instants $t=0$ and $t=t_1$. During this step, the control of the circuit is such that:

- Q1 and D3 conduct,
- Q2, D1 and D4 are blocked,
- 10 - D2 is blocked if the voltage in output SP with respect to earth is, in absolute value, sufficiently low.

Figure 4H illustrates a second step of the operating cycle, between the instants $t=t_1$ and $t=t_2$. During this step, the command of the circuit is such that:

- D1 conducts,
- Q1, Q2, D2, D3 and D4 are blocked.

Figure 4I illustrates a third step of the operating cycle, between the instants $t=t_2$ and $t=t_3$. During this step, the command of the circuit is such that:

- Q2 and D4 conduct,
- Q1, D1, D2 and D3 are blocked.

Figure 4J illustrates a fourth step of the operating cycle, between the instants $t=t_3$ and $t=T$. During this step, the command of the circuit is such that:

- D2 conducts,
- 30 - Q1, Q2, D1, D3 and D4 are blocked.

Figures 4K to 4N concern an operating mode where the output current "is" is positive, for an operating cycle (from $t=0$ to $t=T$).

Figure 4K illustrates a first step of the operating cycle, between the instants $t=0$ and $t=t_1$. During this step, the command of the circuit is such that:

- Q1 and D3 conduct,
- Q2, D1, D2 and D4 are blocked.

Figure 4L illustrates a second step of the operating cycle, between the instants $t=t_1$ and $t=t_2$. During this step, the command of the circuit is such that:

- D1 conducts,
- Q1, Q2, D2, D3 and D4 are blocked.

Figure 4M illustrates a third step of the operating cycle, between the instants $t=t_2$ and $t=t_3$. During this step, the command of the circuit is such that:

- Q2 and D4 conduct
- Q1, D2 and D3 are blocked,
- D1 is blocked if the voltage in output SP with respect to earth is, in absolute value, sufficiently low.

Figure 4N illustrates a fourth step of the operating cycle, between the instants $t=t_3$ and $t=T$. During this step, the command of the circuit is such that

- D2 conducts,
- Q1, Q2, D1, D3 and D4 are blocked.

Figure 5E shows the chronograms corresponding to the operating mode illustrated by figures 4G to 4J, therefore for an operating cycle comprising four steps.

5 Figure 5F shows the chronograms corresponding to the operating mode illustrated by figures 4K to 4N, therefore for an operating cycle also comprising four steps.

10 Figure 6a shows the principle of using the converter according to the invention as voltage source by the addition of means 11 of measuring the differential voltage between the outputs SP and SM, a suitable equaliser 12 receiving a set point E_c and a suitable modulator 13. The outputs of the modulator 13
15 supply the command voltages SQ1 and SQ2 of the transistors Q1 and Q2.

 Figure 6b shows the principle of using the converter according to the invention as current source by the addition of means 21 of measuring "is" output
20 currents of the converter, a suitable equaliser 22 receiving a set point E_c and a suitable modulator 23. The outputs of the modulator 23 supply the command voltages SQ1 and SQ2 of the transistors Q1 and Q2.

CLAIMS

1. Chopping converter supplied by a positive voltage (V_p) and a negative voltage (V_m) with respect to earth, and delivering an output voltage between a first output terminal (SP) and a second output terminal (SM), the latter terminal being connected directly to earth or through a resistor, comprising two windings (L_s , L_p) wound in opposition around a magnetic core, the number of turns of the second winding (L_p) being greater than the number of turns of the first winding (L_s), the first end of the first winding (L_s) being connected to a mid point of a first branch connecting the positive voltage (V_p) to the negative voltage (V_m) and comprising a first diode (D_1) and a second diode (D_2) inversely mounted, the mid point of the first branch being situated between the first diode (D_1) and the second diode (D_2), the second end of the first winding (L_s) being connected to earth, the first end of the second winding (L_p) being connected to a mid point of a second branch connecting the positive voltage (V_p) to the negative voltage (V_m), the part of the second branch connecting its mid point to the positive voltage (V_p) comprising, arranged in series, a first switch forming means (Q_1) and a third diode (D_3) directly mounted in relation to the positive voltage (V_p) and together forming a unidirectional switch with direct and inverse blocking capability, the part of the second branch connecting its mid point to the negative voltage (V_m) comprising, arranged in series, a second switch forming means (Q_2) and a fourth

diode (D4) directly mounted in relation to the negative voltage (Vm) and together forming a unidirectional switch with direct and inverse blocking capability, the second end of the second winding (Lp) being connected
5 to the output terminal (S).

2. Chopping converter according to claim 1, in which a smoothing capacitor (Cs) is connected between the first output terminal (SP) of the converter
10 and earth.

3. Chopping converter according to one of claims 1 or 2, in which, in the second branch connecting the positive voltage (Vp) to the negative
15 voltage (Vm), said arrangement in series consists in arranging the first (Q1) and second (Q2) switch forming means on the side of the respective positive or negative voltages and arranging the third (D3) and fourth (D4) diodes on the side of the mid point of the
20 second branch.

4. Chopping converter according to any of claims 1 to 3, in which the first (Q1) and second (Q2) switch forming means are chosen among MOS transistors,
25 bipolar transistors and IGBT transistors or any other switch having a bidirectional conduction capability and a direct blocking capability.

5. Chopping converter according to any of
30 claims 1 to 4, further comprising means (11) of measuring the output voltage of the converter, this

measuring means delivering an output signal representative of the output voltage to a first input of a regulation means (12) in which a second input receives a set point signal, the regulation means (12) delivering a signal supplied to the input of a modulator (13) in which a first output sends a command signal (SQ1) to the first switch forming means (Q1) and in which a second output sends a command signal (SQ2) to the second switch forming means (Q2), the converter being thereby configured in voltage source.

6. Chopping converter according to any of claims 1 to 4, further comprising means (21) of measuring the output current (is) of the converter, this measuring means delivering an output signal representative of the output current of the converter to a first input of a regulation means (22) in which a second input receives a set point signal, the regulation means (22) delivering a signal supplied to the input of a modulator (23) in which a first output sends a command signal (SQ1) to the first switch forming means (Q1) and in which a second output sends a command signal (SQ2) to the second switch forming means (Q2), the converter being configured in current source.

25

7. Electromechanical actuator control comprising a chopping converter according to any of claims 1 to 6.

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8. Regulating automaton comprising a chopping converter according to any of claims 1 to 6.

9. Terrestrial, naval or aeronautic equipment comprising a chopping converter according to any of claims 1 to 6.

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10. Turbine engine comprising a chopping converter according to any of claims 1 to 6.

11. Method for operating a chopping
10 converter according to any of claims 1 to 6, the converter being supplied by a positive voltage (V_p) and a negative voltage (V_m) with respect to earth, the converter delivering an output current (i_s) in a load (Z) connected between the first output terminal (SP)
15 and the second output terminal (SM), the method comprising the following steps, for an operating cycle and to pass a negative current in the load (Z):

- a first step during which a first switch forming means (Q_1) are open, the fourth diode (D_4) is
20 conducting, the second switch forming means (Q_2) are closed and the first (D_1), second (D_2) and third (D_3) diodes are blocked during a first part of the cycle, the converter operating in continuous mode or in discontinuous mode,

25 - a second step, following the first step, during which, the first (Q_1) and second (Q_2) switch forming means are open, the second diode (D_2) is conducting and the first (D_1), third (D_3) and fourth (D_4) diodes are blocked during a second part of the
30 cycle, this second part of the cycle not ending the cycle if the converter operates in discontinuous mode

and ending the cycle if the converter operates in continuous mode,

- a third step, following the second step if the converter operates in discontinuous mode, during which the first (Q1) and second (Q2) switch forming means are open and the first (D1), second (D2), third (D3) and fourth (D4) diodes are blocked during a third part of the cycle ending at the end of the cycle.

12. Method for operating a chopping converter according to any of claims 1 to 6, supplied by a positive voltage (V_p) and a negative voltage (V_m) with respect to earth, the converter delivering an output current (i_s) in a load (Z) connected between the first output terminal (SP) and the second output terminal (SM), the method comprising the following steps, for an operating cycle and to pass a positive current in the load (Z):

- a first step during which a first switch forming means (Q1) are closed, the third diode (D3) is conducting, the second switch forming means (Q2) are open and the first (D1), second (D2) and fourth (D4) diodes are blocked during a first part of the cycle, the converter operating in continuous mode or in discontinuous mode,

- a second step, following the first step, during which the first diode (D1) is conducting, the first (Q1) and second (Q2) switch forming means are open and the second (D2), third (D3) and fourth (D4) diodes are blocked during a second part of the cycle, this second part of the cycle not ending the cycle if

the converter operates in discontinuous mode and ending the cycle if the converter operates in continuous mode,

- a third step, following the second step if the converter operates in discontinuous mode, during which the first (Q1) and second (Q2) switch forming means are open, the first (D1), second (D2), third (D3) and fourth (D4) diodes are blocked, during a third part of the cycle ending at the end of the cycle.

10 13. Method for operating a chopping converter according to any of claims 1 to 6, supplied by a positive voltage (V_p) and a negative voltage (V_m) with respect to earth, the converter delivering an output current (i_s) in a load (Z) connected between the first output terminal (SP) and the second output terminal (SM), the method comprising the following steps, for an operating cycle and to pass a negative current in the load (Z), the converter operating in continuous mode:

- 20 - a first step during which a first switch forming means (Q1) are closed, the third diode (D3) is conducting, the second switch forming means (Q2) are open and the first (D1) and fourth (D4) diodes are blocked, the second diode (D2) being blocked if the voltage to the first output (SP) with respect to earth is, in absolute value, sufficiently low during a first part of the cycle,

- a second step, following the first step, during which the first diode (D1) is conducting, the first (Q1) and second (Q2) switch forming means are

open and the second (D2), third (D3) and fourth (D4) diodes are blocked during a second part of the cycle,

- a third step, following the second step, during which the second switch forming means (Q2) are closed, the fourth diode (D4) is conducting, a first switch forming means (Q1) are open and the first (D1), second (D2) and third (D3) diodes are blocked, during a third part of the cycle,

- a fourth step, following the third step, during which the second diode (D2) is conducting, the first (Q1) and second (Q2) switch forming means are open and the first (D1), third (D3) and fourth (D4) diodes are blocked, during a fourth part of the cycle ending at the end of the cycle.

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14. Method for operating a chopping converter according to any of claims 1 to 6, the converter being supplied by a positive voltage (V_p) and a negative voltage (V_m) with respect to earth, the converter delivering an output current (i_s) in a load (Z) connected between the first output terminal (SP) and the second output terminal (SM), the method comprising the following steps, for an operating cycle and to pass a positive current in the load (Z), the converter operating in continuous mode:

- a first step during which a first switch forming means (Q1) are closed, the third diode (D3) is conducting, the second switch forming means (Q2) are open, the first (D1), second (D2) and fourth (D4) diodes are blocked during a first part of the cycle,

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- a second step, following the first step, during which the first diode (D1) is conducting, the first (Q1) and second (Q2) switch forming means are open and the second (D2), third (D3) and fourth (D4) diodes are blocked during a second part of the cycle,
- a third step, following the second step, during which the second switch forming means (Q2) are closed, the fourth diode (D4) is conducting, a first switch forming means (Q1) are open, the second (D2) and third (D3) diodes are blocked, the first diode (D1) is blocked if the voltage to the first output (SP) with respect to earth is, in absolute value, sufficiently low, during a third part of the cycle,
- a fourth step, following the third step, during which the second diode (D2) is conducting, the first (Q1) and second (Q2) switch forming means are open and the first (D1), third (D3) and fourth (D4) diodes are blocked, during a fourth part of the cycle ending at the end of the cycle.