REPUBLIC OF SOUTH AFRICA
PATENTS ACT, 1978

FORM P.8
(to be lodged in duplicate)

A&A Ref: **145043**

PUBLICATION PARTICULARS AND ABSTRACT
(Section 32(3)(a) - Regulations 22(1)(g) and 31)

21	01	PATENT APPLICATION NO	22	LODGING DATE	43	ACCEPTANCE DATE
		2002/00255		**2 January 2002**		2.4.2003

51	INTERNATIONAL CLASSIFICATION	NOT FOR PUBLICATION
	H03K	CLASSIFIED BY: **ISA**

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EARLIEST PRIORITY CLAIMED	COUNTRY		NUMBER		DATE	
	33	**EPO(BE)**	31	**99870159.3**	32	**15 July 1999**

NOTE: The country must be indicated by its International Abbreviation - see schedule 4 of the Regulations

54	TITLE OF INVENTION

Method for protecting power semiconductors of a power converter and converter implementing same

57	ABSTRACT (NOT MORE THAN 150 WORDS)

NUMBER OF SHEETS 26

The sheet(s) containing the abstract is/are attached.

~~If no classification is furnished, Form P.9 should accompany this form.~~
The figure of the drawing to which the abstract refers is attached.

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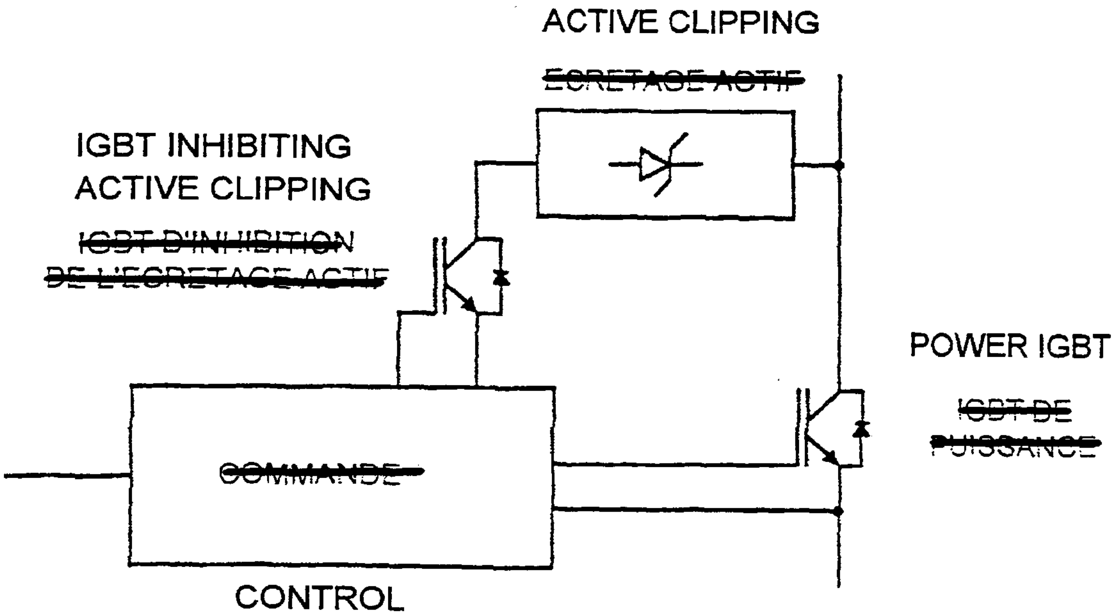

(57) **Abstract:** The invention concerns a method for protecting a power switch in a power converter, associated with voltage threshold clipping, which consists in maintaining the maximum possible voltage at the power switch terminals by inhibiting the voltage threshold clipping function when the power switch is off. The invention also concerns a converter implementing said method.

(5[redacted]r-tisseur de puissance, associé à un dispositif d'écrêtage à seuil de tension, selon lequel [redacted] de la tension maximale admissible aux bornes de l'interrupteur [redacted] la fonction d'écrêtage à seuil de tension lorsque l'interrupteur de [redacted]

PROCESS FOR PROTECTING THE POWER SEMICONDUCTORS OF A POWER CONVERTER AND CONVERTER IMPLEMENTING THIS PROCESS

Field of the invention

The present invention relates to a process for protecting the power semiconductors of a power converter.

The present invention also relates to the converter for carrying out this process.

Background of the invention

In power electronics, electrical conversion systems (DC-AC, AC-DC, DC-DC and AC-AC converters) use controlled semiconductors which act as electrical switches, such as bipolar transistors, thyristors, GTOs, MOSFETs, IGBTs, etc. These semiconductors intrinsically have a limitation as regards the maximum permissible voltage at their terminals. Under certain circumstances, it is desired to control the switch so as to make it conductive (by closing it), at least partially, to prevent an overvoltage from arising across it and destroying it. It is for this reason that various protective circuits have been developed.

This concern is seen, for example, in the design of the supply circuits of electric propulsion motors (synchronous, asynchronous and direct-current). These consist of converters such as, for example, three-phase inverters associated with choppers, in which the semiconductors used as switches must have a voltage withstand that is at least equivalent to and preferably several times the nominal DC catenary voltage. In particular, semiconductors which can withstand overvoltages of 2 to 3 times the catenary voltage are chosen.

In particular, in the case of high voltages, that is to say nominal DC catenary voltages of greater than

2000 V, semiconductors with a relatively high maximum voltage withstand should be used. In addition, these semiconductors should have a linear functioning, as opposed to transistors of "on-off" type. A judicious choice of such semiconductors is IGBTs, which allow increasingly high maximum voltage withstands ranging upto 6.5 kV.

In the description hereinbelow, the example taken is that of switches of IGBT type, since these are switches that can withstand relatively high voltages, and in any case voltages greater than 2 kV, whereas bipolar power transistors and MOSFETs are limited to a maximum voltage of about 1000 V.

In addition IGBTs have intrinsic qualities of speed and ease of control.

However, when the maximum voltages are lower, it is common practice to arrange several switches (semiconductors) in series. In this case, it is essential to combine them with a clipping system. This is particularly true in the case of IGBTs, which allow a relatively low voltage withstand (of about 3.3 kV).

The operating principle of an active clipping device is simple: the switch is closed when the voltage across it exceeds a predetermined value. To this end, a voltage threshold device (Zener, Transil, etc. avalanche diodes) is inserted between one power terminal and the switch control means.

The active clipping device is thus a device that serves to protect the IGBT against transient overvoltages. When an overvoltage appears, the clipping device becomes actuated by closing the IGBT, which will then conduct in its linear zone. The voltage threshold at and above which the clipping device is actuated is calculated so that the voltage across the IGBT never reaches its maximum permissible voltage. Physically, the clipping circuit is arranged between the collector and the gate of an IGBT so as to create a reaction loop that is as fast as possible.

This voltage threshold circuit reinjects a control current when the voltage across the switch exceeds a predetermined value (for example 2200 V). The drawback is that this device lowers the maximum voltage threshold permissible by the switch when this switch is not conducting, that is to say when the switch is open for a converter at rest.

When the voltage across the IGBT-active clipping device assembly exceeds 2.2 kV, the power switch will be turned on (closed) and the voltage across it will thus be maintained at about 2.2 kV instead of 3.3 kV permitted as the maximum permissible voltage.

From a static point of view, in the case of an uncontrolled IGBT, and thus an open IGBT, the maximum voltage that the circuit composed of the IGBT and the active clipping device can withstand is the clipping threshold, which is considerably less than the maximum permissible voltage of the IGBT. In the above example, the IGBT has a maximum permissible voltage of 3.3 kV and an active clipping device whose threshold is 2.2 kV is added to it: a device which, at rest, is uncontrollable above 2.2 kV is thus obtained.

Prior art

Document JP-06 163 911 describes in very general terms a device for determining whether the voltage of a MOSFET drain is greater than the voltage of a Zener diode taken up in an associated clipping circuit. It is very probably a device intended to be used in integrated circuits with relatively low voltages of the order of a few tens of volts at the very maximum.

Aims of the invention

The present invention aims to propose a process for protecting a power converter supplied with high voltage, allowing switches to withstand the maximum permissible high voltage across them when they are open, in the case where a clipping system is included.

Main characteristic elements of the invention

The present invention relates to a process for protecting a power switch present in a power converter, associated with a voltage threshold clipping device, according to which the maximum permissible voltage across the power switch is maintained by snubbing the voltage threshold clipping function when the power switch is off.

Preferably, the maximum permissible voltage across the power switch is maintained with the aid of a snubber switch placed between the voltage threshold clipping device and the power switch control means.

According to one preferred embodiment, the same control means is used to control the snubber switch and the power switch.

Advantageously, the leading edge of the control pulse of the snubber switch is synchronized with that of the control pulse of the power switch and the trailing edge of the control pulse of the snubber switch has a delay on that of the power switch pulse. Preferably, said delay is between 50 and 500 μs and is preferably close to 200 μs.

The present invention also relates to a power converter comprising at least one power switch associated with a voltage threshold clipping device, characterized in that it further comprises a snubber switch placed between the voltage threshold clipping device and the power switch control means.

According to one preferred embodiment, the converter comprises several power switches arranged in series, said switches being associated with a voltage threshold clipping device.

Advantageously, the power switch(es) is (are) high voltage linear-regime semiconductors such as power IGBTs.

Preferably, the snubber switch is placed in series with the clipping device, the assembly being connected between the collector and the gate of the power IGBT.

Advantageously, the snubber switch is a linear-regime semiconductor, preferably an IGBT, or a semiconductor of "on-off" type.

In addition, the snubber switch may be controlled by the same control means as the power switch(es), by means of a suitable circuit.

Finally, the present invention relates to the use of the process and the converter described above for protecting power switches present in a voltage-reducing chopping circuit against overvoltages.

Brief description of the drawings

Figure 1 shows the schematic diagram of an active clipping device or a voltage threshold clipping device mounted on a power switch.

Figure 2 shows the schematic diagram of a snubber-IGBT active clipping device mounted between the voltage threshold component and the power IGBT control means for implementing the process according to the invention.

Figure 3 shows the control waveforms of the power IGBT and of the clipping IGBT.

Figure 4 shows the whole schematic diagram of the clipping snubber circuit.

Figure 5 shows the whole schematic diagram of a voltage-reducing chopping circuit.

Detailed description of the invention

Figure 1 shows the schematic diagram of a power switch provided with a voltage threshold device. To snub active clipping, a second switch is inserted in the clipping loop. This switch must be able to withstand a high voltage and must be fast. The choice of an IGBT in a small housing is adopted to satisfy these criteria. It will be referred to hereinbelow as a snubber switch or snubber IGBT.

The voltage of the snubber IGBT must be such that the system thus formed can, when static, recover all or some of the maximum permissible voltage of the power IGBT. If one again takes the example of an IGBT which has a maximum permissible voltage of 3.3 kV and to which is added an active clipping device with a threshold of 2.2 kV, the maximum permissible voltage of the snubber IGBT must be at least 3.3 - 2.2 = 1.1 kV.

Among the many possibilities for controlling the snubber IGBT, one has been chosen which is derived from the control pulses of the power IGBT, thus making it possible to render the clipping snubber function transparent with respect to the control electronics. The strategy for controlling the snubber IGBT is described in Figure 2. Care should be taken to ensure that the snubber IGBT is definitely closed before the moment at which the power IGBT enters its linear zone, whether this is during turning on or turning off. When the control pulse of the power IGBT disappears, clipping is still allowed for about 200 µs (Toff).

The active clipping device with its snubber circuit may be applied to any electrical conversion system liable to suffer switching overvoltages (chopper, inverter, half-bridge rectifier, etc.).

The whole schematic of the clipping snubber circuit is shown in Figure 3, in which V29 is the snubber IGBT, with a maximum permissible voltage of 1.2 kV. The clipping circuit, the voltage threshold of which is 2.2 kV, consists of the diode V34, resistors R11 and R2, switches X14 and X13, diodes V22 to V1 and the capacitor C1.

This circuit receives the pulses from the power IGBT via the connection X20; it converts them as described in Figure 2 and applies them to the snubber IGBT.

X18 is the connection that goes to the gate of the power IGBT (via an auxiliary circuit) whereas X1 is connected to its collector.

The specific example given here uses the device in the context of placing IGBT power switches in forward series. Figure 4 shows the application schematic of this: it is a chopper in which are arranged 3 IGBTs (U1: V1, V2, V3) in series and also two diodes (U2: V1, V2) in series. By means of the clipping snubber device, the voltage that the chopper can withstand is equal to three times the maximum permissible voltage at each IGBT, i.e. 3 × 3.3 kV = 9.9 kV. Without the clipping snubber device, the voltage would only be 3 × 2.2 kV = 6.6 kV, which is insufficient for a conventional 3 kV line network.

CLAIMS

1. Process for protecting a power switch present in a power converter, associated with a voltage threshold clipping device, according to which the maximum permissible voltage across the power switch is maintained by snubbing the voltage threshold clipping function when the power switch is turned off.

2. Process according to Claim 1, characterized in that the maximum permissible voltage across the power switch is maintained with the aid of a snubber switch placed between the voltage threshold clipping device and the power switch control means.

3. Process according to Claim 1 or 2, characterized in that the same control means is used to control the snubber switch and the power switch.

4. Process according to Claim 3, characterized in that the leading edge of the control pulse of the snubber switch is synchronized with that of the control pulse of the power switch and in that the trailing edge of the control pulse of the snubber switch has a delay on that of the power switch pulse.

5. Process according to Claim 4, characterized in that said delay is between 50 and 500 μs and preferably close to 200 μs.

6. Power converter associated with a clipping device, comprising:

- at least one power switch,
- a control means for said power switch,
- a snubber switch placed between the voltage threshold clipping device and the power switch control means,

said control means making it possible to control both the power switch and the snubber switch.

7. Converter according to Claim 6, characterized in that it comprises several power switches arranged in series, said switches being associated with a voltage threshold clipping device.

8. Converter according to Claim 6 or 7, characterized in that the power switch(es) is (are) high voltage linear-regime semiconductors such as power IGBTs.

9. Converter according to Claim 8, characterized in that the snubber switch is placed in series with the clipping device, the assembly being connected between the collector and the gate of the power IGBT.

10. Converter according to any one of Claims 6 to 9, characterized in that the snubber switch is a linear-regime semiconductor, preferably an IGBT, or a semiconductor of "on-off" type.

11. Use of the process according to any one of Claims 1 to 5 or of the converter according to any one of Claims 6 to 10, to protect power switches present in a voltage-reducing chopping circuit against overvoltages.

12. A process as claimed in Claim 1, substantially as herein described and illustrated.

13. A converter as claimed in Claim 6, substantially as herein described and illustrated.

14. Use as claimed in Claim 11, substantially as herein described and illustrated.

15. A new process for protecting a power switch, a new converter, a new use of a process as claimed in any one of Claims 1 to 5, or a new use of a converter as claimed in any one of Claims 6 to 10, substantially as herein described.

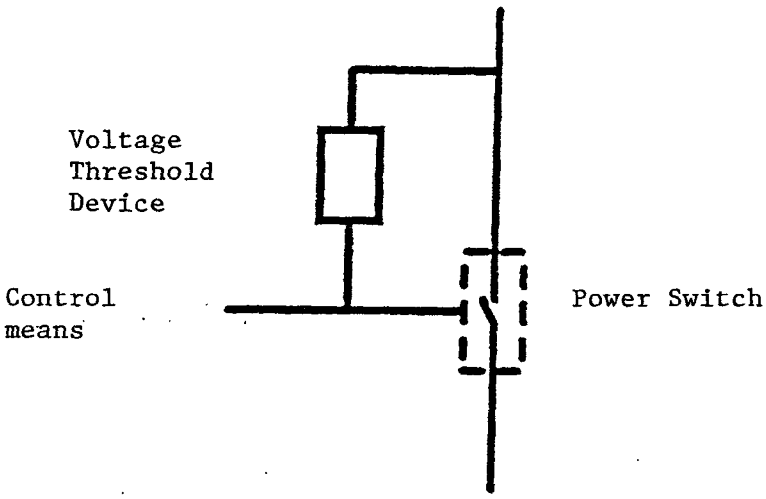

Fig. 1

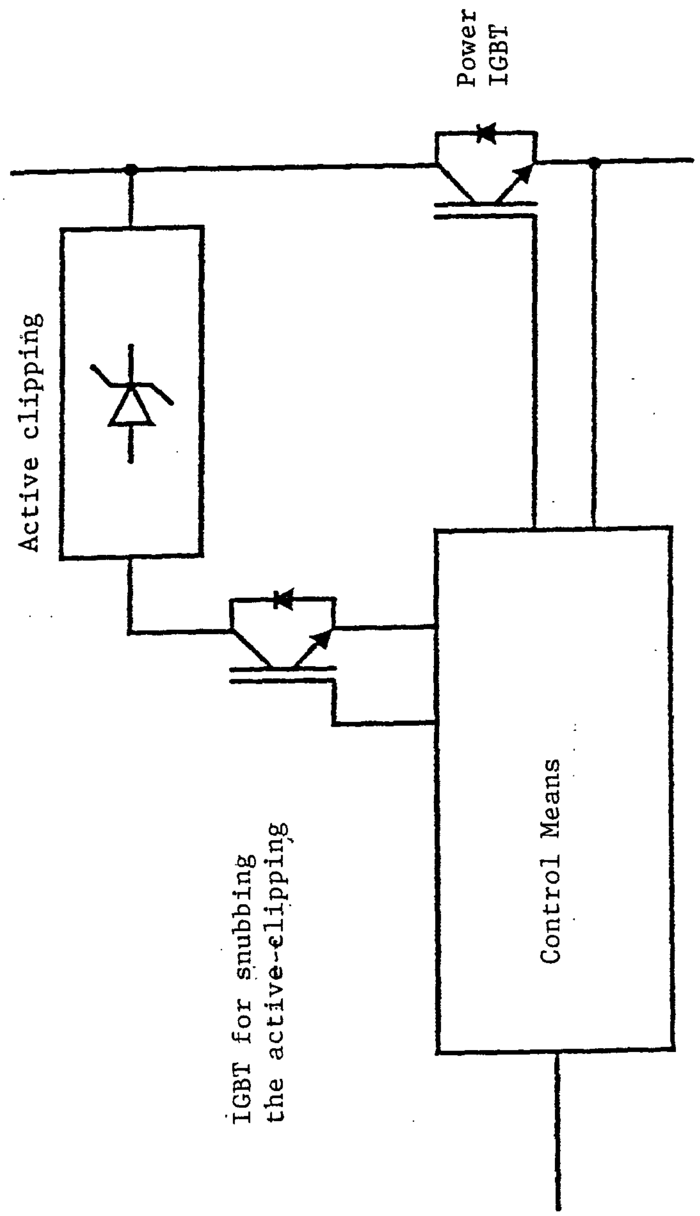
Power
IGBT
Active clipping
IGBT for snubbing
the active-clipping
Control Means

Fig. 2

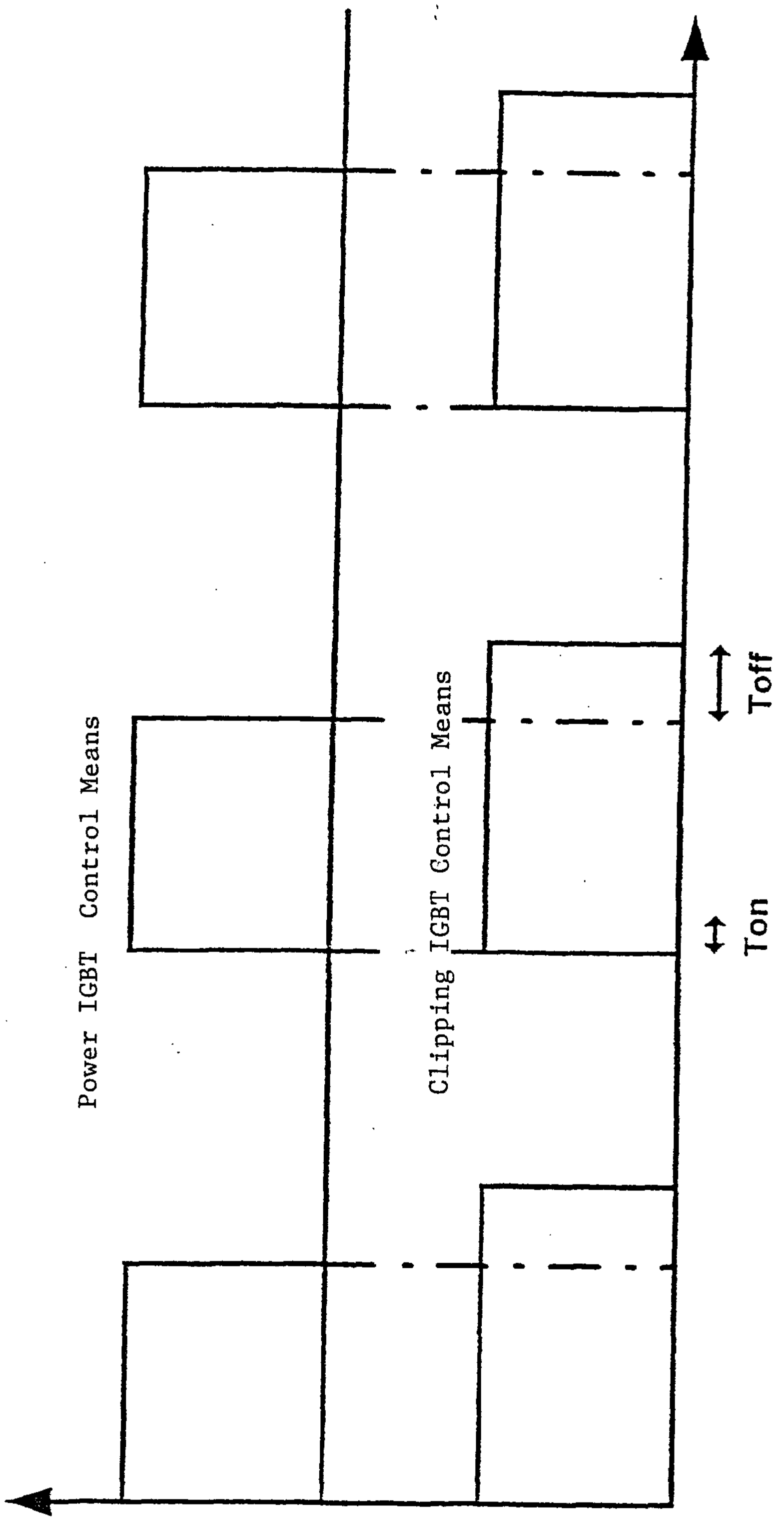
Power IGBT Control Means
Clipping IGBT Control Means
Ton
Toff

Fig. 3

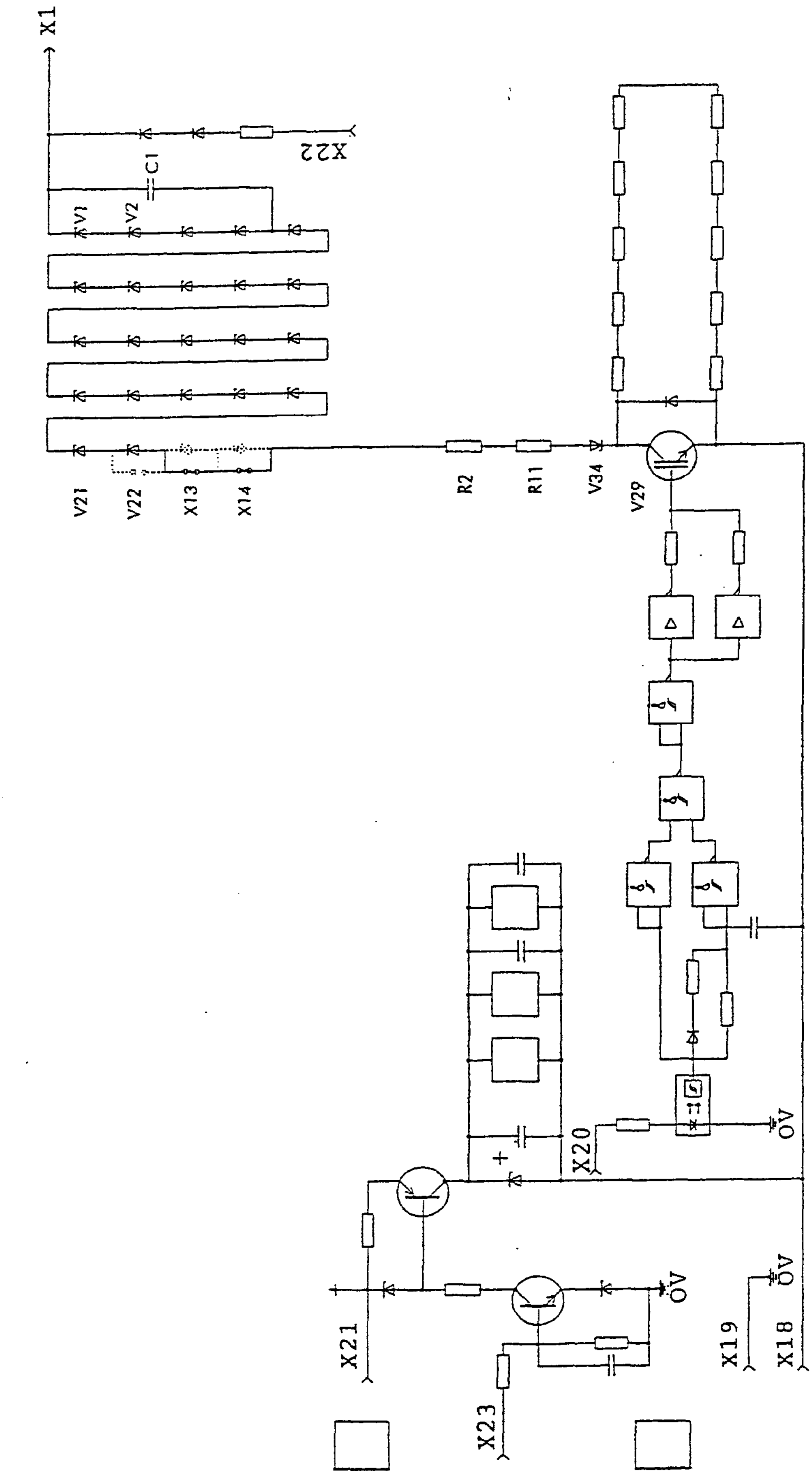
X1
X22
C1
V1
V2
V21
V22
X13
X14
R2
R11
V34
V29
X20
0V
X21
X23
0V
0V
X19
X18

Fig. 4

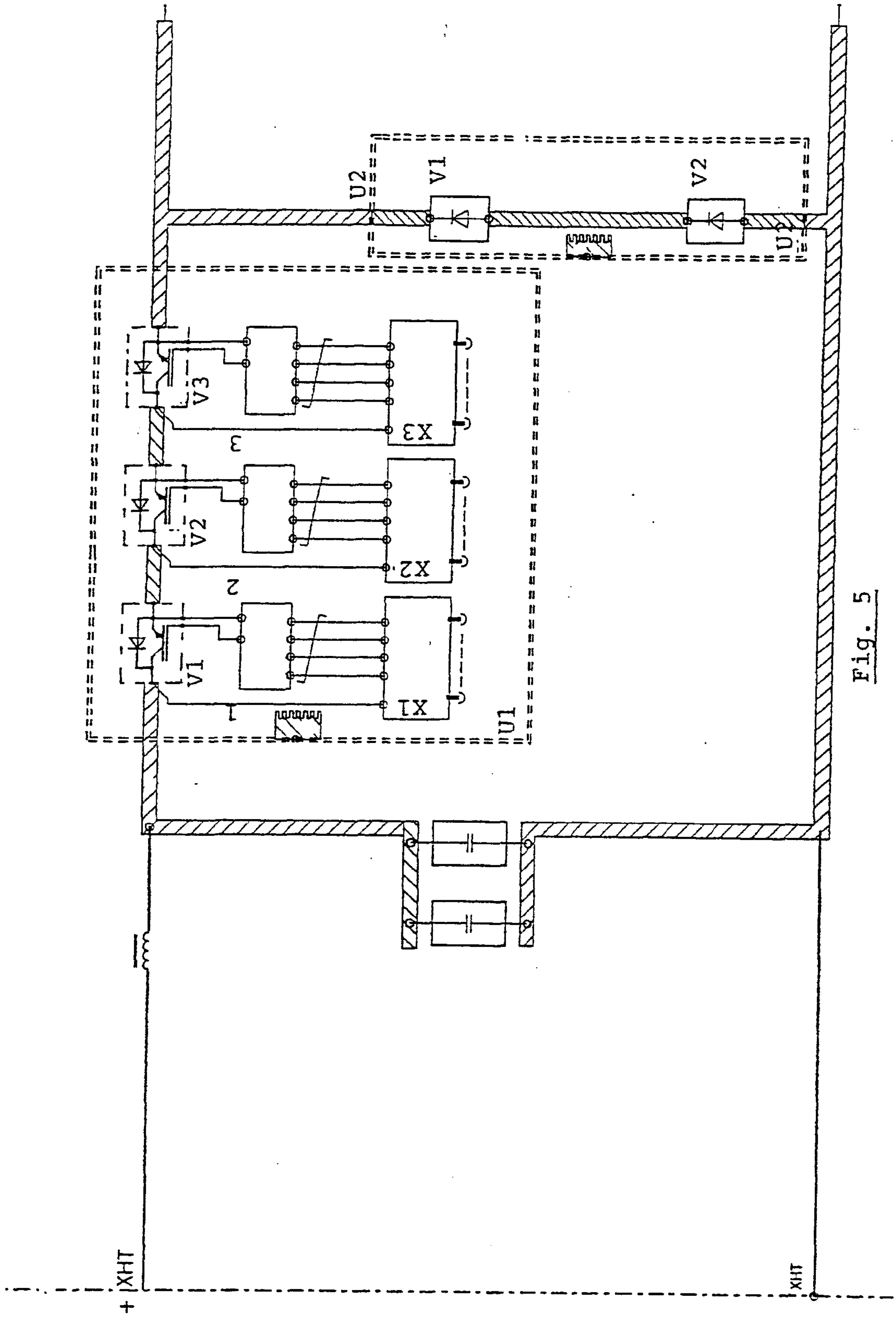

Fig. 5