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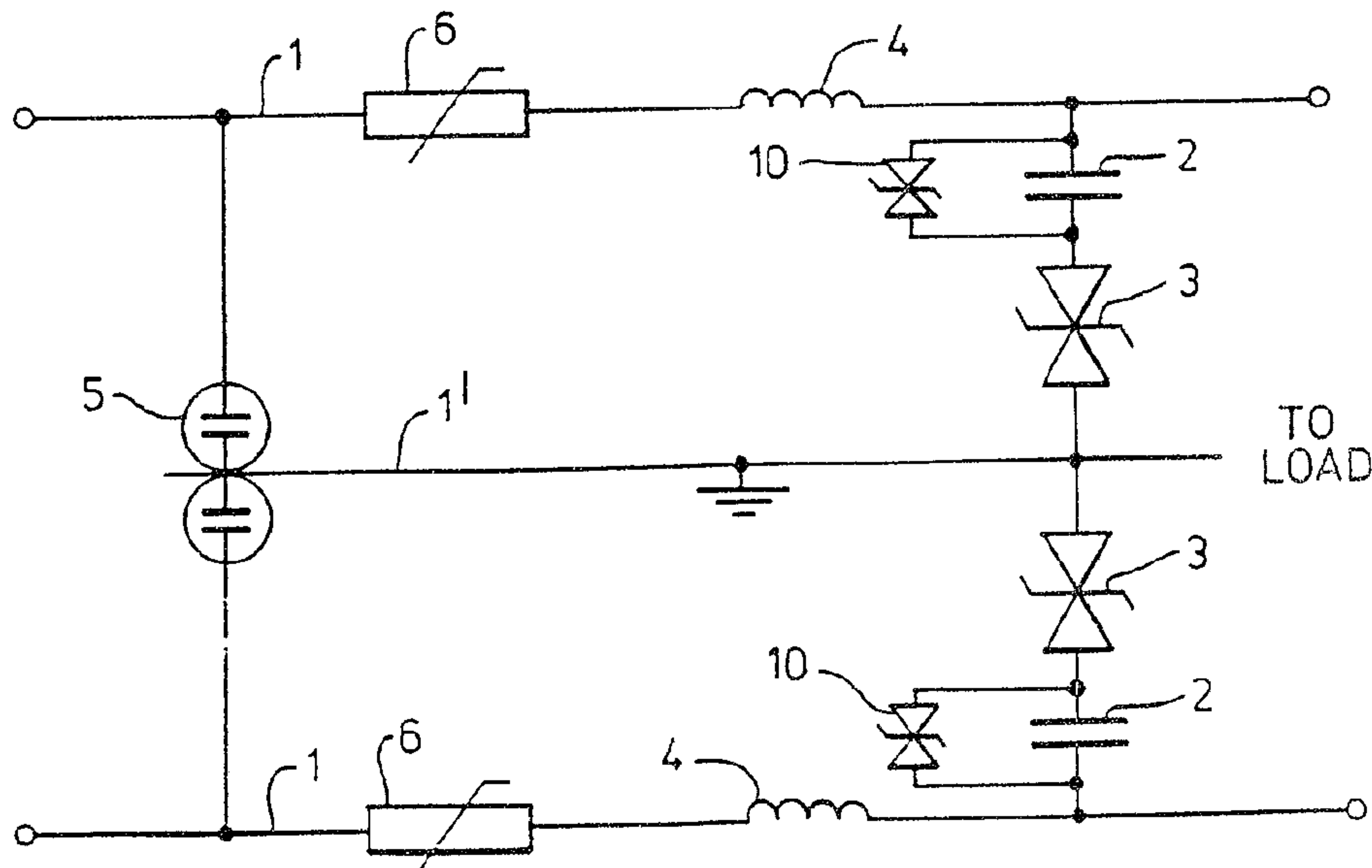
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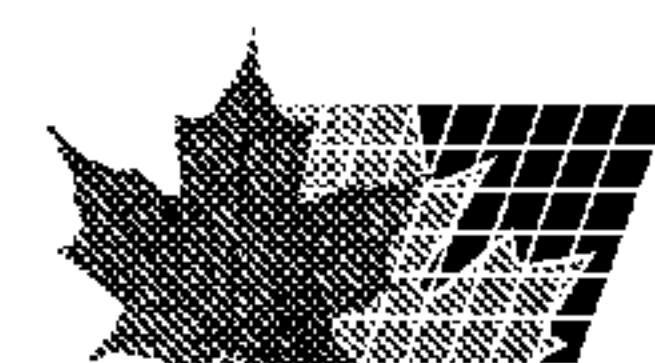
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(57) Abrégé/Abstract:

An arrangement for protecting an electrical circuit such as a telephone circuit from a voltage transient comprises a voltage clamp or foldback device (3) arranged to be connected between a current-carrying line (1) and ground (1'), a capacitor (2) in series with it, and an inductance (4) series connected in the line. During normal operation the arrangement acts as an LC filter whose high frequency break-point is determined by the capacitance of the voltage clamp or foldback device (3) and the value of the inductance (4) which are chosen to give a break point of 1 kHz to 10 MHz. However, when the arrangement is subjected to a voltage transient, the voltage clamp or foldback device (3) fires causing the break-point to fall to a value determined by the values of the capacitor (2) and inductance (4). The arrangement may be used, for example, to protect the circuit against a rapid voltage drop caused by the firing of another circuit protection device such as a gas discharge tube (5).





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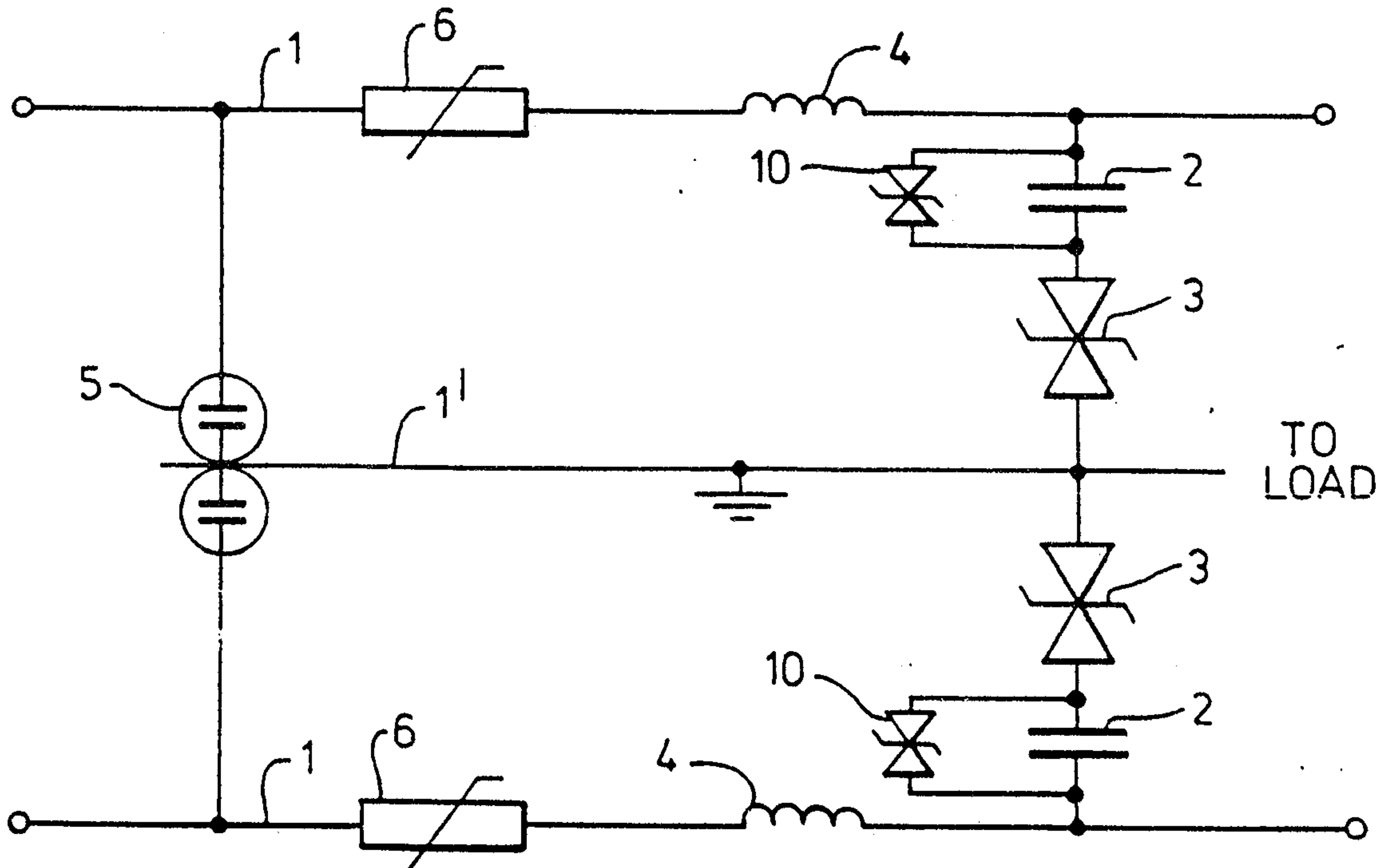
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(57) Abstract

An arrangement for protecting an electrical circuit such as a telephone circuit from a voltage transient comprises a voltage clamp or foldback device (3) arranged to be connected between a current-carrying line (1) and ground (1'), a capacitor (2) in series with it, and an inductance (4) series connected in the line. During normal operation the arrangement acts as an LC filter whose high frequency break-point is determined by the capacitance of the voltage clamp or foldback device (3) and the value of the inductance (4) which are chosen to give a break point of 1 kHz to 10 MHz. However, when the arrangement is subjected to a voltage transient, the voltage clamp or foldback device (3) fires causing the break-point to fall to a value determined by the values of the capacitor (2) and inductance (4). The arrangement may be used, for example, to protect the circuit against a rapid voltage drop caused by the firing of another circuit protection device such as a gas discharge tube (5).

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Arrangement for Protecting Telecommunications Equipment from
Voltage Transients

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This invention relates to the protection of telecommunications equipment from voltage transients.

10 Voltage transients may be produced in electrical circuits by a variety of methods, for example by lightning, electrostatic discharge or pulses generated by operation of electrical equipment. These phenomena may all induce very large currents on cables and structures such as, for example telecommunications equipment,
15 aircraft, and ships which can penetrate and damage electrical systems, either causing hardware damage such as semiconductor damage or electronic upset such as transmission loss or loss of stored data.

20 Electrostatic discharges are extremely fast discharges from a capacitor such as a human body. These discharges, because they can be so local, present a great threat to the individual electronic components. Induced electrical transients caused by lightning represent a threat to electrical/electronic equipment especially in
25 telecommunications equipment.

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According to the present invention, there is provided an arrangement for protecting an electrical circuit, for example telecommunications equipment, from a voltage transient, which comprises a voltage clamping device
5 connected or arranged to be connected between a current-carrying line of the circuit and ground, a capacitor having a capacitance up to $1\mu\text{F}$ connected in series with the voltage clamping device, an inductance of from $1\mu\text{H}$ to 100mH series connected in the line, and a high-energy foldback device
10 connected or arranged to be connected between the current-carrying line and ground, under normal operating conditions, the arrangement acting as an LC filter whose high frequency break-point is determined by the capacitance of the voltage clamping device (and any additional capacitor optionally
15 connected in parallel therewith) and the inductance and is in the range of from 1kHz to 10MHz , the high frequency break-point falling when the arrangement is subjected to a voltage transient sufficient to cause the voltage clamping device to conduct, to a value that is determined by the
20 values of the capacitor and the inductance.

The voltage clamping device may be selected from a number of devices that have voltage limiting properties, for example a back-to-back diode arrangement in which the diodes may comprise semiconductor diodes, avalanche diodes or Zener
25 diodes. Alternatively, non-linear resistors may be employed such as zinc oxide, silicon carbide or other varistor materials. The voltage clamping device may, if desired, comprise a MIM or nin device or a gaseous voltage regulator.

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The preferred voltage clamping devices are bidirectional clamping diodes, for example as sold under the tradename TransZorb. The clamping devices will normally have a stray capacitance in the range of from 10 pF to 10 nF and especially from 100 pF to 5 nF. In some instances the stray capacitance of the voltage clamping device may be too low, in which case a small capacitor may be connected in

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parallel with it to bring the resultant capacitance within the preferred range.

As stated above, the inductance has a value, in the range of
 5 from $1\mu\text{H}$ to 100 mH preferably it has a value of upto 1mH. This may,
 for example be achieved by utilizing the stray inductance of a wire
 wound resistor. In some circumstances it may be preferable instead
 to employ a small inductor. The inductance will normally have an
 associated resistance of from 1 to 50 ohms, especially from 3 to 10
 10 ohms. The resistance may be chosen so that the total resistance of all
 series connected components in the line is within acceptable limits.

The capacitor has a capacitance of upto $1\mu\text{F}$, and preferably
 has a capacitance of at least 100pF, especially at least 10nF. In most
 15 cases it will be preferred for the capacitor to have a capacitance that is
 at least ten times the stray capacitance of the voltage clamping device,
 and preferably at least 100 times the stray capacitance. Where the
 capacitance is 100 times that of the voltage clamping device the high
 frequency break point should fall when subjected to a transient, to
 20 about one tenth the frequency of the break point under normal
 operating conditions.

The arrangement according to the invention has the advantage
 that under normal operating conditions it acts as a low pass filter with
 25 a relatively high break point, but that when it is subjected to a
 transient its high frequency gain is immediately reduced
 significantly. Thus, for example, where the break point falls to one
 tenth of its original frequency the gain magnitude at frequencies above
 the normal operating break point will be reduced by 40 dB.

30 The high-energy foldback device employed in the arrangement
 is intended to protect the circuit against higher energy, longer
 duration overvoltages. It may, for example, comprise a spark gap or
 gas discharge tube (GDT), or a voltage controlled triac, connected
 35 between the conductor and ground for shunting high energy

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transients to ground. Such components can, in some circumstances, cause damage to the circuit they are used to protect by forming pulses having very rapidly changing voltages. For example, if a GDT is subjected to a transient that has a rising edge of 1kV us^{-1} it may switch at, say, 500 V whereupon the transient voltage falls to zero in about 1 ns, thereby causing the transient that is transmitted to have a falling edge of 500 kV us^{-1} . Such a rate of change of voltage can cause permanent damage to the circuit load. However, in the present invention, the reduction in the break point frequency caused by switching of the voltage clamp device will reduce the slope of the falling edge of that part of the transient that is let through the arrangement.

In addition the arrangement may include an overcurrent protection device series connected in the line between the additional, higher energy overvoltage device and the voltage clamping device in order to protect the circuit from long lasting overvoltages, for example caused by system failure, or by accidental or malicious connection of mains supply. Suitable devices include positive temperature coefficient (PTC) devices, eg. ceramic or polymeric PTC devices, preferably polymeric devices, for example as described in US patents Nos. 4,238,812 and 4,329,726 to Middleman et al. Such devices are available from Raychem Corporation under the registered trademark "PolySwitch".

Since the circuit acts as a low pass filter both in its unswitched and switched state, it has the disadvantage that it cannot protect the circuit from DC or very low frequency overvoltages that are not great enough to cause the GDT or PTC device to switch. This may be overcome by connecting an additional voltage clamp or a foldback device across the capacitor. In this case the voltage clamp in series with the capacitor and the clamp or foldback device connected across the capacitor should have a combined clamping or threshold voltage that is greater than the normal equipment voltage. The term "foldback device" as used here is intended to mean a device which

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exhibits a high electrical resistance, eg. at least 100 kohms, preferably at least 1 Mohm, and especially at least 10 Mohms, at low electrical voltages but whose resistance falls from a high value to a low value, eg. less than 10 ohms, when subjected to a high voltage (the lowest such voltage being referred to as the "threshold voltage"). The device will remain in its low resistance state only for as long as a small holding current is maintained through the device, otherwise it will automatically revert to its high resistance state. Suitable foldback devices include voltage controlled triacs, voltage controlled thyristors and gas discharge tubes.

The arrangement according to the invention may be employed in telephone equipment where, for example, a balanced pair of lines having a common ground is used. In this case a circuit protection unit may be employed which comprised a pair of substantially identical arrangements according to the invention arranged to be series connected in a pair of current-carrying lines and connected to a common ground.

Two forms of arrangement according to the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a circuit diagram of one form of arrangement in accordance with the invention;

Figure 2 is a diagram of the circuit of figure 1 with some of the parasitic values shown;

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Figure 3 is a Bode diagram showing the performance of the circuit of figure 1; and

Figure 4 is a circuit diagram of a modification of the circuit shown in figure 1.

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Referring to Figure 1 of the accompanying drawings, a five terminal telephone circuit protection module has a balanced pair of lines 1 and a common ground line 1'. Two identical circuit protection arrangements are provided, one associated with each line of the module. The arrangements each comprise a bidirectional voltage clamping diode 3 connected between the line 1 and ground 1', a 100 nF capacitor 2 connected in series with the clamping diode 3, and a 200 uH inductor 4 in series connected in the line. In addition, the arrangement includes a GDT 5 connected between the line 1 and ground, and a PTC device 6 series connected in the line. The PTC device 6 has a low temperature resistance of about 6 ohms so that the total line resistance of the module is 6 ohms plus the resistance of the inductor 4.

Figure 2 shows the circuit of figure 1 and indicates the most important stray quantities, namely the stray capacitance 7 of the voltage clamping device 3 and the resistance 8 of the inductor 4. Capacitance 7 is approximately 2 nF and resistance 8 is 5.6 ohms.

The performance of the arrangement is shown in Figure 3. In normal operation the arrangement acts as a low pass RLC filter whose capacitance is given by the series connected capacitor 2 and stray capacitance of the clamping diode 3. When the unit is subjected to a voltage transient the clamping diode 3 will clamp the voltage between the line 1 and ground, with the result that the capacitance of the filter circuit is given by capacitor 2 above. The break point of the filter is therefore reduced to about one tenth the frequency of the original break point and the gain at frequencies above the normal operating break point is reduced by about 40 dB. When the GDT fires, the voltage on the line 1 will fall to zero within about 1 ns which corresponds to a voltage reduction of about $500 \text{ kV } \mu\text{s}^{-1}$. The reduced frequency band of the filter will, however, limit the rate of fall of the voltage at the output of the unit to about $500 \text{ V } \mu\text{s}^{-1}$.

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Figure 4 shows a modification of the circuit shown in figure 1 which will provide protection to a circuit against DC overvoltages. This circuit corresponds to that shown in Figure 1 with the addition of a further bidirectional voltage clamping diode 10 connected across the
5 capacitor 2. The clamping diode 10 has a breakdown voltage such that the sum of the breakdown voltages of the two diodes 3 and 10 is greater than the maximum system voltage.

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CLAIMS:

1. An arrangement for protecting an electrical circuit from a voltage transient, which comprises a voltage clamping device connected or arranged to be connected
5 between a current-carrying line of the circuit and ground, a capacitor having a capacitance up to $1\mu\text{F}$ connected in series with the voltage clamping device, an inductance of from $1\mu\text{H}$ to 100mH series connected in the line, and a high-energy foldback device connected or arranged to be connected
10 between the current-carrying line and ground, under normal operating conditions, the arrangement acting as an LC filter whose high frequency break-point is determined by the capacitance of the voltage clamping device (and any additional capacitor optionally connected in parallel
15 therewith) and the inductance and is in the range of from 1kHz to 10MHz , the high frequency break-point falling, when the arrangement is subjected to a voltage transient sufficient to cause the voltage clamping device to conduct, to a value that is determined by the values of the capacitor
20 and the inductance.

2. An arrangement as claimed in claim 1, wherein the inductance has a value of up to 1mH .

3. An arrangement as claimed in claim 1 or 2 which has a total series resistance in the range of from 1 to 50
25 ohms.

4. An arrangement as claimed in claim 3, which has a total series resistance in the range of from 3 to 10 ohms.

5. An arrangement as claimed in any one of claims 1 to 4, wherein the high frequency break-point, when the

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arrangement is subjected to a voltage transient sufficient to cause the voltage clamping device to conduct, occurs at a frequency not higher than 0.1 times the frequency of the break-point under normal operation.

5 6. An arrangement as claimed in claim 5, wherein the high energy foldback device is a gas discharge tube or a voltage controlled triac.

7. An arrangement as claimed in any one of claims 1 to 6, which includes an overcurrent protection device series
10 connected in the current-carrying line.

8. An arrangement as claimed in claim 7, wherein the overcurrent protection device is a PTC device.

9. An arrangement as claimed in any one of claims 1 to 8, which includes an additional voltage clamping or a
15 foldback device connected across the capacitor, the voltage clamping device and the additional voltage clamping or foldback device having a combined clamping or threshold voltage that is greater than the normal equipment voltage.

10. A circuit protection unit, which comprises a pair
20 of substantially identical arrangements as claimed in any one of claims 1 to 9 arranged to be series connected in a pair of current-carrying lines and connected to a common ground.

11. A telecommunications equipment having a current-
25 carrying line and ground and an arrangement as claimed in any one of claims 1 to 9.

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12. A telecommunications equipment having a pair of current-carrying lines and ground and a circuit protection unit as claimed in claim 10.

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OTTAWA, CANADA

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Fig.1.

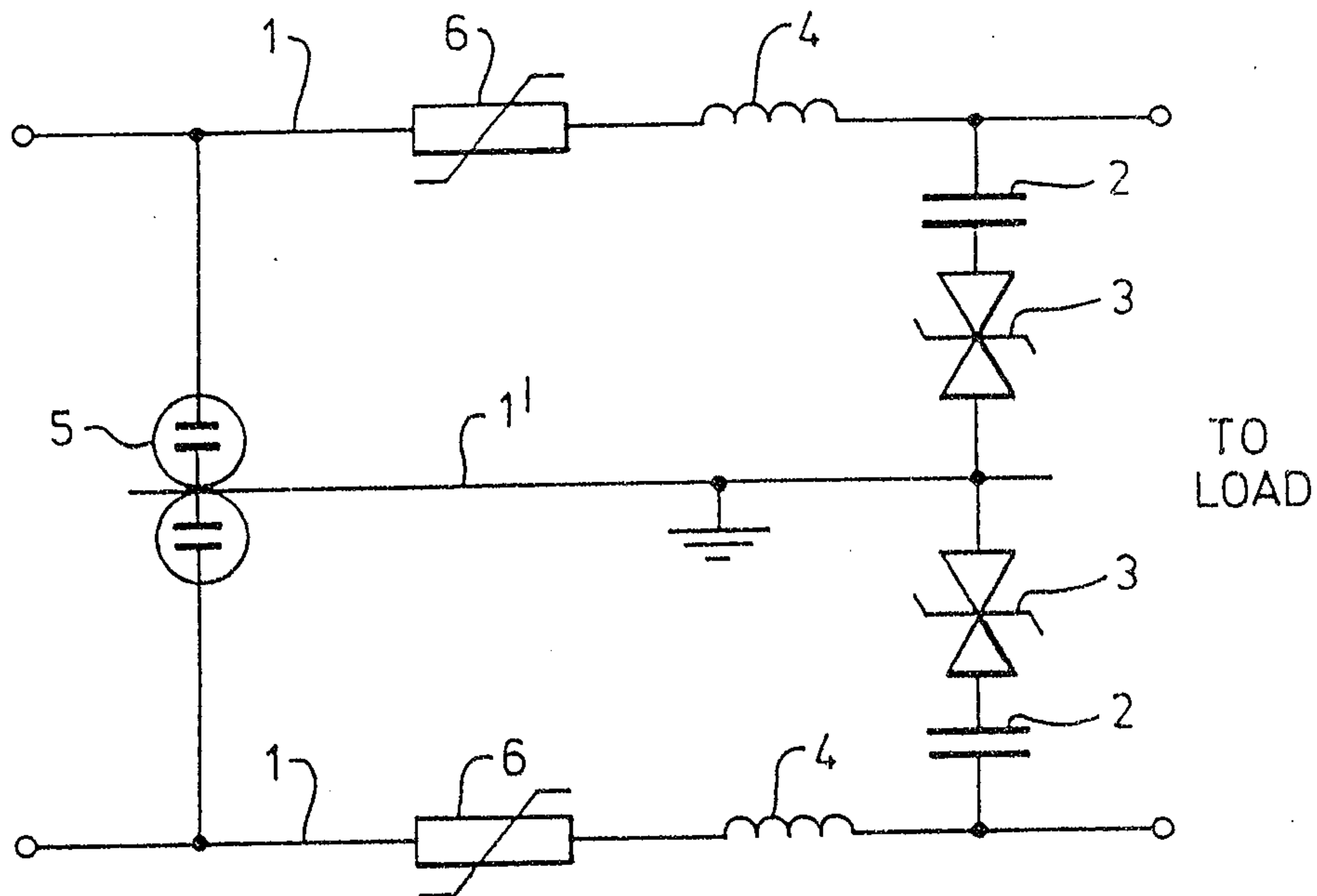
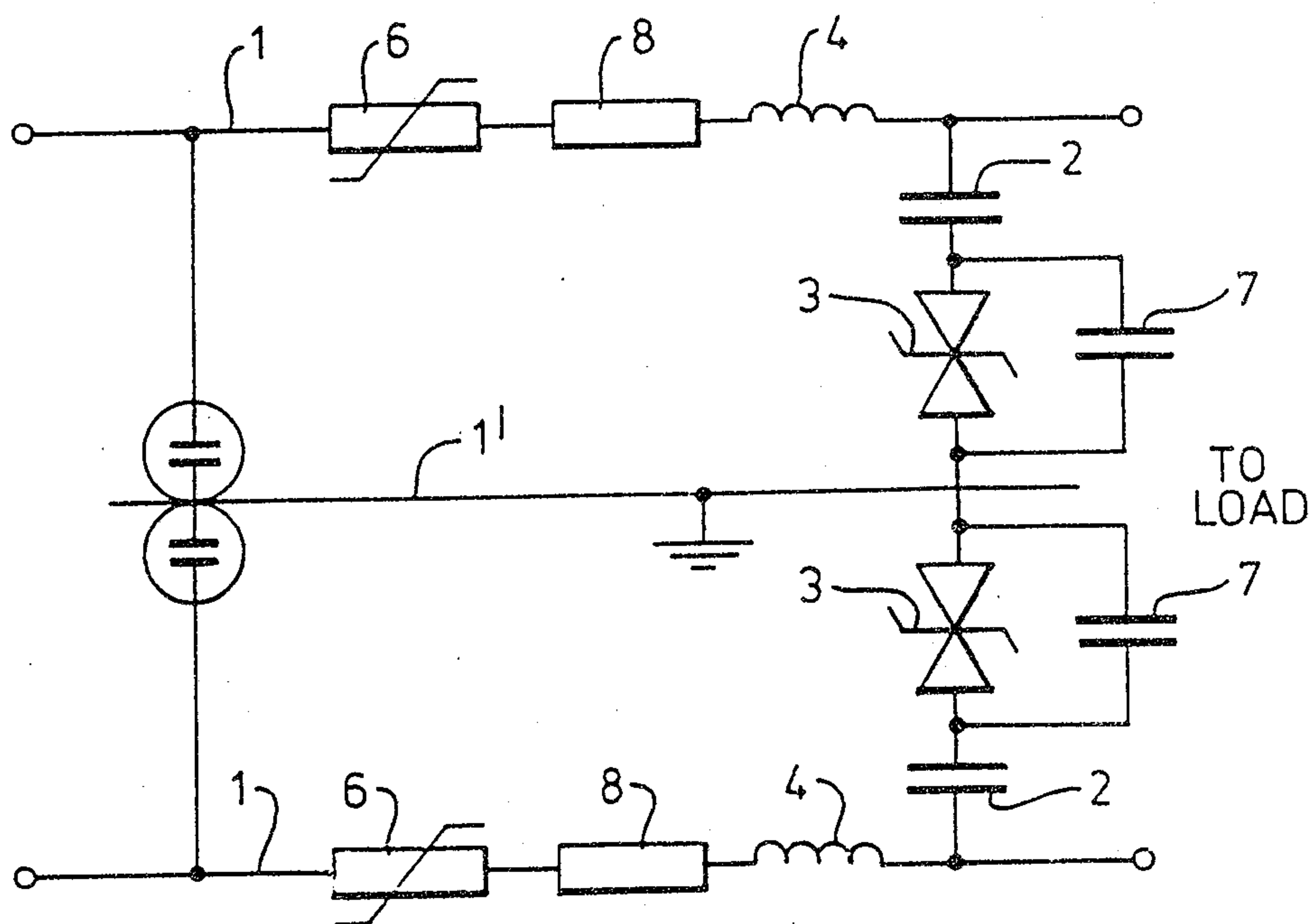


Fig.2.



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Fig.3.

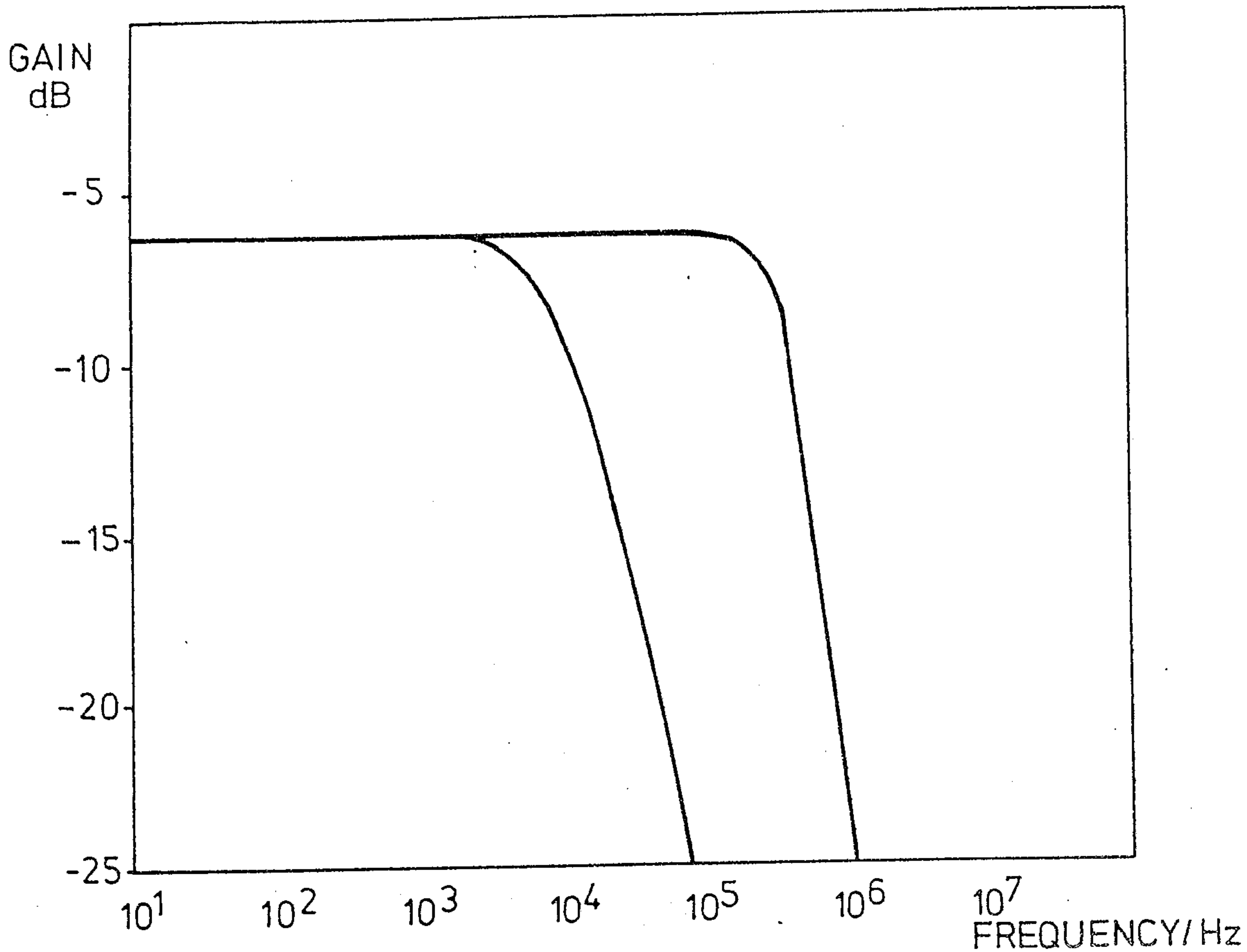


Fig.4

