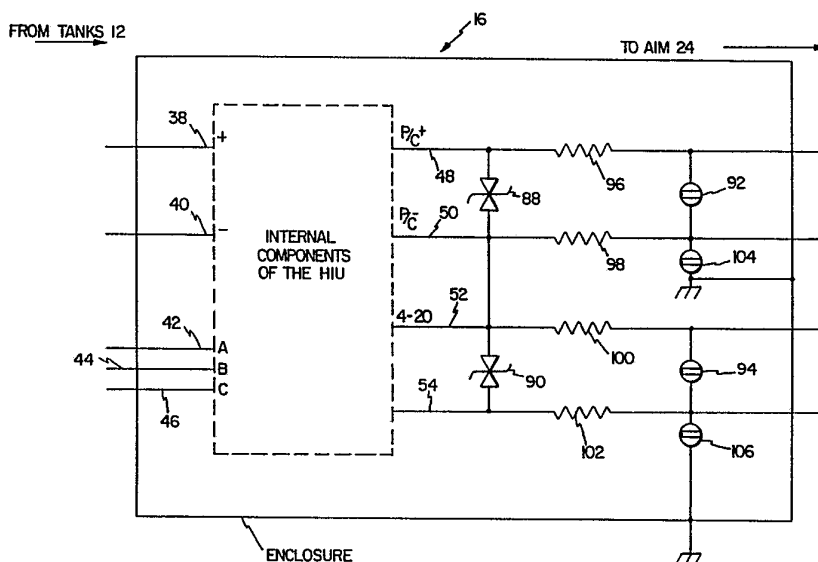




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(54) Title: IMPROVED LIGHTNING PROTECTION FOR FIELD MOUNTED INSTRUMENTS



(57) Abstract

A protection circuit is provided for protecting sensitive electrical field instruments from a transient voltage strike and for ensuring that the instruments will meet safety approval during high potential voltage testing. The first and second wires (52, 54) of a two-wire circuit are connected to a first and second terminal respectively. A first surge arrester electrically couples a first path between the first and second terminal. An impedance (100, 102) and a transient suppressor (90) are connected in series and electrically couple a second path between the first and second terminal. The second path is coupled in parallel with the first path between the first and second terminal and is coupled closer to the internal components of the electrical instruments to be protected than is the first path. A second surge arrester (106) is electrically coupled between the second terminal and ground, and has a higher voltage breakdown potential than the first surge arrester (94).

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**IMPROVED LIGHTNING PROTECTION FOR  
FIELD MOUNTED INSTRUMENTS**

**BACKGROUND OF THE INVENTION**

This invention relates to an apparatus for  
5 protecting solid state electrical circuits in a grounded  
enclosure from transients induced on lines coming into  
the enclosure when there is a lightning strike, while  
also maintaining low leakage electrical isolation when  
a high test potential ("hi-pot test") is applied between  
10 the electrical circuits and the grounded enclosure.

Known protection circuits couple between each  
line and the grounded enclosure. Each protection  
circuit includes a gas filled surge arrestor coupled  
between two conductors (line to enclosure). A current  
15 limiting impedance, such as a resistor or inductor, in  
series with a solid state transient suppressor, such as  
a metal oxide varistor (NOV), are also coupled between  
the two conductors. This impedance limits current to  
the transient suppressor and allows sufficient voltage  
20 to build up to fire the surge arrestor.

The surge arrestor shunts large currents (many  
thousands of amps); however, it is slow to fire or turn  
on. The transient suppressor responds more rapidly;  
however, it can shunt only lower levels of current.

25 When there is an induced transient, the  
transient suppressor will conduct before the gas filled  
surge arrestor and limit the potential applied to the  
protected circuit to a level compatible with the maximum  
rating of the protected circuit. The potential drop  
30 across the impedance allows enough potential across the  
surge arrestor to fire it, which then shunts larger  
currents.

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To avoid undesired circulation of ground currents in circuit conductors and avoid coupling energized circuit conductors to the enclosure, electrical isolation is desired between the circuitry and the enclosure. This isolation is tested by connecting all circuit lines together and imposing a high potential, typically 500 VAC or 700 VDC, between the lines and the enclosure which is normally grounded. Leakage current is measured with the high potential applied and is required to be at a low level, typically 5 milliamperes (mA) or less.

when the hi-pot voltage test is applied to a field mounted instrument having circuitry which includes protective components, these protective components will conduct and shunt current to the enclosure. Therefore, the leakage will exceed the 5mA leakage current specification. In the past, hi-pot tests were done on instruments with the lightning protection circuits disconnected, and then the lightning protection circuits were reconnected before placing the instrument in service. New test methods require that the lightning protection circuits remain connected while the hi-pot test is performed. The existing lightning protection circuits, however, produce too much leakage through the transient suppressor, and the instrument does not meet the leakage standard.

Thus, there is a need for protection circuitry which will not only better protect the field mounted instruments from an induced transient, but will also ensure that the field mounted instruments will meet leakage limits during high potential voltage testing.

#### SUMMARY OF THE INVENTION

The protection circuitry of the present invention protects a pair of terminals of a field

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instrument from lightning and other electrical transients. The protection circuitry includes first and second surge arrestors, a first transient suppressor, and first impedance means.

5           The first surge arrestor is connected between the first and second terminals, and the second surge arrestor is connected between the second terminal and a grounded enclosure. The first transient suppressor and the first impedance means are connected in series  
10 between the first and second terminals.

The second surge arrestor preferably has a higher breakdown voltage than the first surge arrestor, and provides the ability of the protection circuitry to pass hi-pot isolation testing.

15           In embodiments in which there are more than two terminals to be protected, the additional terminals are protected by additional surge arrestors, transient suppressors, and impedance means.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20           FIG. 1 is a block diagram of a tank gauging system which uses field mounted instruments having the protection circuitry of the present invention.

25           FIG. 2 is a schematic diagram of the improved lightning protection circuitry for a hydrostatic interface unit in accordance with the present invention.

FIG. 2A is a schematic diagram, similar to FIG. 2, in which communication lines are shorted together for safety approval testing.

30           FIG. 3 is a schematic diagram of the improved lightning protection circuitry for an application interface module in accordance with the present invention.

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FIG. 3A is a schematic diagram, similar to FIG. 3, in which communication lines are shorted together for safety approval testing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5           FIG. 1 shows one preferred embodiment of a tank gauging system 10. In FIG. 1, a relatively small tank gauging system is depicted with dashed lines indicating additional connections for systems including more tanks and more associated equipment than are shown  
10 in FIG. 1. Tank gauging system 10 includes tanks 12, 13, 14, and 15, hydrostatic interface units (HIUs) 16, 17, 18, and 19, level gauges 20, 21, 22, and 23, application interface modules (AIMs) 24 and 25, translators 26 and 27 and control room equipment 28. In  
15 this preferred embodiment, tank 12 is fitted with three sensors: RTD temperature sensor 29, middle level pressure transmitter 30, and bottom level pressure transmitter 31. Likewise, tank 13 is fitted with three  
20 sensors: RTD temperature sensor 32, middle pressure transmitter 33, and bottom pressure transmitter 34. HIUs 16, 17, 18, and 19 are each connected to the sensors on a tank for receiving the sensor outputs as shown in FIG. 1.

          HIUs 16, 17, 18, and 19 transmit tank level  
25 information and other parameters over long cables to AIMs 24 and 25 using serial communication such as the SP-50 (draft standard) bus communication. AIMs 24 and 25 receive tank level information from HIUs 16, 17, 18, and 19 and retransmit the information to control  
30 equipment 28 via an RS-485 bus as shown in FIG. 1.

          Level gauges 20, 21, 22, and 23 sense tank 30 levels in tanks such as tanks 14 and 15 and transmit level information over mark-space busses to translators 26 and 27 as shown in FIG. 1. Translators 26 and 27

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translate the level information to an RS-485 format and transmit the information over the RS-485 bus to control room equipment 28.

5 In addition to carrying information, busses can also carry energization current for the various pieces of equipment.

FIG. 2 is a detailed drawing of the lightning protection system for protecting HIU 16 from a lightning induced transient which may occur between HIU 16 and AIM 10 24. Transient suppressor 88 electrically couples between positive power/communication line 48 and negative power/communication line 50; and transient suppressor 90 couples between four-twenty (4-20) 15 milliamp lines 52 and 54. Gas-filled surge arrestors 92 and 94 also electrically couple between positive power/communication line 48 and negative power/communication line 50, and four-twenty (4-20) 20 milliamp lines 52 and 54, respectively as shown in FIG. 2. Impedances 96, 98, 100, and 102 limit the current flow in positive power/communication line 48, negative power/communication line 50, and four-twenty (4-20) 25 milliamp lines 52 and 54, respectively. Gas-filled surge arrestor 104 electrically couples negative power/communication line 50 to the enclosure which is connected to earth ground, while gas-filled surge 30 arrestor 106 electrically couples line 54 to the grounded enclosure.

In operation, the lightning protection circuitry shown in FIG. 2 will protect the internal 30 circuitry of HIU 16 from a lightning induced transient between HIU 16 and AIM 24, while not presenting any leakage paths through solid state components to the grounded enclosure during a high potential voltage test.

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The protection circuitry electrically coupling four-twenty (4-20) milliamp line 52 to line 54 is substantially similar to the circuitry electrically coupling positive power/communication line 48 to negative power/communication line 50. Therefore, only the circuitry protecting positive power/communication line 48 and negative power/communication line 50 will be discussed.

when there is a lightning strike inducing a transient, transient suppressor 88, which can be a metal oxide varistor (MOV) or Zener diodes, conducts and limits the voltage between positive power/communication line 48 and negative power/communication line 50 to a level below the maximum rating of the internal components of HIU 16. This clamp voltage of the transient suppressor 88 is chosen so that it is small enough to prevent damage to any internal circuitry located inside HIU 16. Generally, this value is between 5 volts and 90 volts, depending on the internal circuitry to be protected.

Large amounts of current are shunted to negative power/communication line 50, allowing enough voltage across impedances 96 and 98 to fire surge arrestor 92, which then shunts even larger currents to negative power/communication line 50. At this point, if there is enough voltage across gas-filled surge arrestor 104, it will fire and shunt current to the enclosure which is grounded. Therefore, the internal components of HIU 16 will be left undamaged from the induced transient.

Lines 38, 40, 42, 44, and 46 shown in FIG. 2 can also be protected with similar circuitry, if desired.

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During a high potential voltage test, all of the input and output lines of HIU 16 are shorted together, as shown in FIG. 2A. At this point, 500 VAC or 700 VDC is connected between the terminals and the grounded enclosure. Therefore, gas-filled surge arrestor 104 must have a firing voltage rating greater than the hi-pot test voltage applied between the terminals to ensure a low level of leakage. At a minimum, this voltage rating must exceed 500 VAC or 700 VDC depending on the test potential applied.

The transient protection circuitry connected between the four-twenty (4-20) milliamp lines 52 and 54 is similar to the circuitry just described between positive power/communication line 48 and negative power/communication line 50.

FIG. 3 is a detailed diagram of lightning protection circuitry which protects the internal circuitry of AIM 24 from an induced transient on lines 64 and 66 between AIM 24 and HIU 16, as well on lines 68, 70, 72, 74 and 76 between AIM 24 and control room equipment 28. The protection circuitry in AIM 24 includes gas filled surge arrestors 108, 136, 138, 140, and 142 connected between lines 64, 66, 68, 70, 72, 74, and 76. Resistors 126, 128, 130, 132, 134 are coupled in series between lines 68, 70, 72, 74, and 76, respectively, and internal components to provide current limiting for transient suppressors 118, 120, 122, and 124. Lines 64 and 66, which carry DC current during normal operation, are protected with current limiting inductors 112 and 114. The current limiting inductors provide a smaller DC voltage drop than would current limiting resistors.

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In FIG. 3, surge arrestors 110 and 144 couple 30 between lines 66 and 76, respectively, and the enclosure to shunt current to the grounded enclosure.

At the onset of a lightning strike, or other  
5 such transient, transient suppressor 116 conducts and limits the voltage between positive power/communication line 64 and negative power/communication line 66 to the component rating for maximum clamping voltage. This component rating is chosen so that it is small enough to  
10 prevent damage to any internal circuitry located inside AIM 24. Generally, this value is between 5 volts and 90 volts, depending on the internal circuitry to be protected.

Large amounts of current are shunted to  
15 negative power/communication line 66, allowing enough voltage across impedances 112 and 114 to fire surge arrestor 108, which then shunts energy to negative power communication line 66. At this time, if there is enough voltage across gas-filled surge arrestor 110, it fires  
20 and shunts energy to earth ground.

During a high potential voltage test, all of the input and output lines of AIM 24 are shorted together, as shown in Figure 3A. At this point, 500 VAC or 700 VDC is connected between the terminals and  
25 ground. Therefore, gas-filled surge arrestors 144 and 110 must have a voltage rating greater than the voltage applied between the terminals to ensure low leakage. At a minimum, this voltage rating must exceed 500 VAC or 700 VDC.

30 The lightning protection circuitry described herein protects sensitive electrical equipment located inside HIU 16 or AIM 24. Similar circuits can also be used in translator 26, for example. The transient suppressors conduct and limit the voltage between the

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protected lines to the component rating for maximum clamping voltage. This component rating should be calculated so that the level is well within the withstand capability of the components used in the product circuitry. However, since the transient suppressor has a limited ability to withstand high current surges, a surge arrestor which has the ability to shunt large amounts of current must be placed in parallel with the transient suppressor. The surge arrestor connected to earth ground must have a large maximum voltage capacity for the circuitry to ensure low leakage of current. During a high potential voltage test, all input and output terminals are connected together and 500 VAC or 700 VDC is applied between the terminals and ground.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

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WHAT IS CLAIMED IS:

1. In a field instrument having first and second terminals for connection to an external device, a protection circuit comprising:
  - a first surge arrestor connected between the first and second terminals;
  - a second surge arrestor connected between the second terminal and ground; and a first transient suppressor and first impedance means connected in series between the first and second terminals.
2. The protection circuit of claim 1 wherein the first impedance means comprises:
  - a first impedance connected between the first terminal and the first transient suppressor; and
  - a second impedance connected between the second terminal and the first transient suppressor.
3. The protection circuit of claim 1 wherein the field instrument includes a third terminal, and further comprising:
  - a third surge arrestor connected between the third terminal and the second terminal; and
  - a second transient suppressor and second impedance means connected in series between the third terminal and the second terminal.
4. The protection circuit of claim 3 wherein the second impedance means comprises:
  - a third impedance connected between the third terminal and the second transient suppressor; and

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the second impedance being connected between the second terminal and the second transient suppressor.

5. The protection circuit of claim 3 wherein the field instrument includes a fourth terminal, and further comprising:

a fourth surge arrestor connected between the fourth terminal and the second terminal;  
and

a third transient suppressor and a third impedance means connected in series between the fourth terminal and the second terminal.

6. The protection circuit of claim 5 wherein the third impedance means comprises:

a fourth impedance connected between the fourth terminal and the third transient suppressor; and

the second impedance being connected between the second terminal and the third fill transient suppressor.

7. The protection circuit of claim 5 wherein the field instrument includes a fifth terminal, and further comprising:

a fifth surge arrestor connected between the fifth terminal and the second terminal;  
and

a fourth transient suppressor and fourth impedance means connected in series between the fifth terminal and the second terminal.

8. The protection circuit of claim 7 wherein the fourth impedance means comprises:

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a fifth impedance connected between the fifth terminal and the fourth transient suppressor; and

the second impedance being connected between the second terminal and the fourth transient suppressor.

9. The protection circuit of claim 1 wherein the first impedance means includes a resistor.

10. The protection circuit of claim 1 wherein the first impedance means includes an inductor.

11. The protection circuit of claim 1 wherein the second surge arrestor has a higher breakdown voltage than the first surge arrestor.

12. The protection circuit of claim 1 wherein the first and second surge arrestors are gas filled tubes.

13. The protection circuit of claim 1 wherein the first transient suppressor includes a solid state device.

14. The protection circuit of claim 1 wherein the field instrument includes third and fourth terminals, the protection circuit further comprising:

a third surge arrestor connected between the third and fourth terminals;

a fourth surge arrestor connected between the fourth terminal and ground; and

a second transient suppressor and second impedance means connected in series between the third and fourth terminals.

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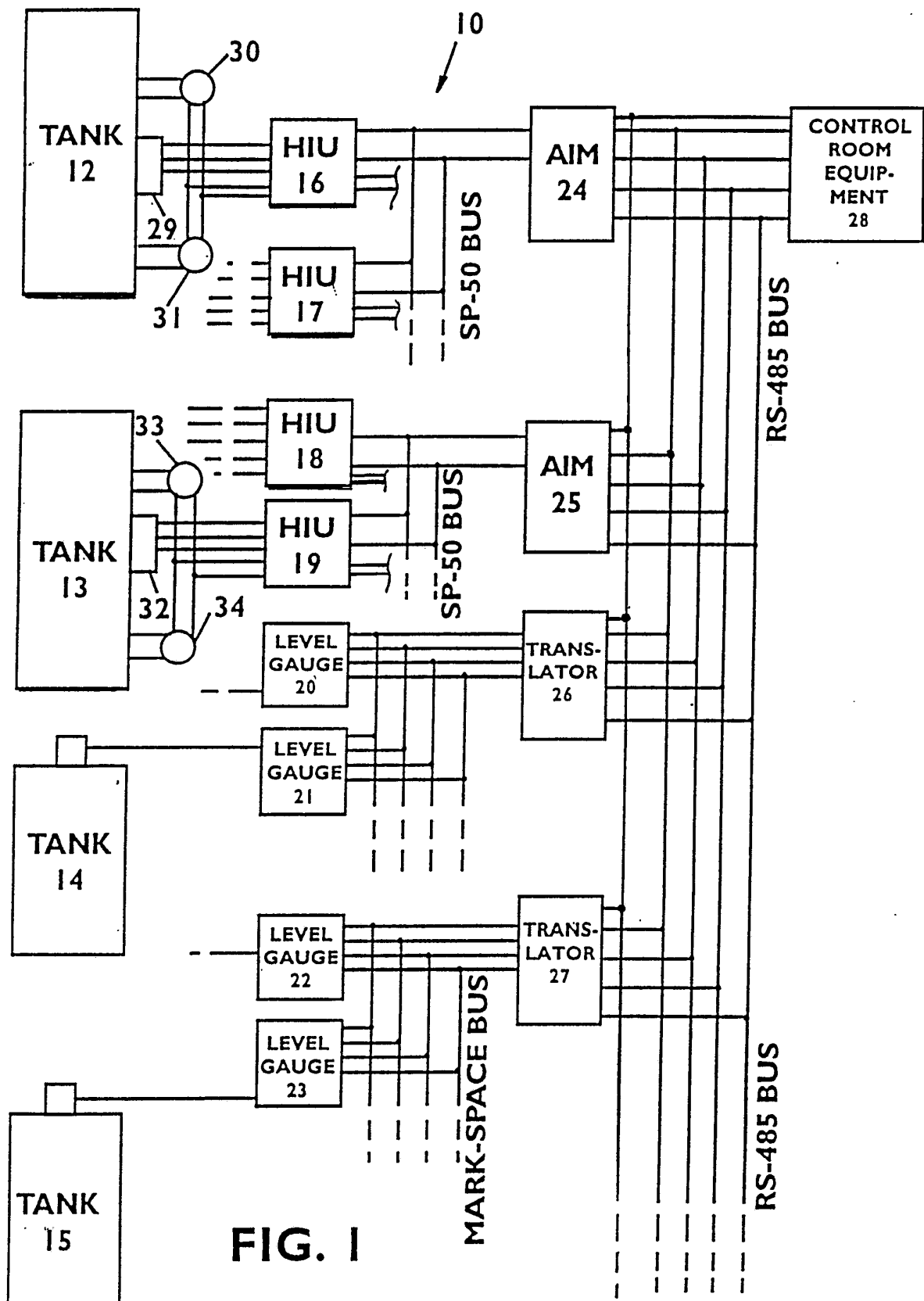


FIG. 1

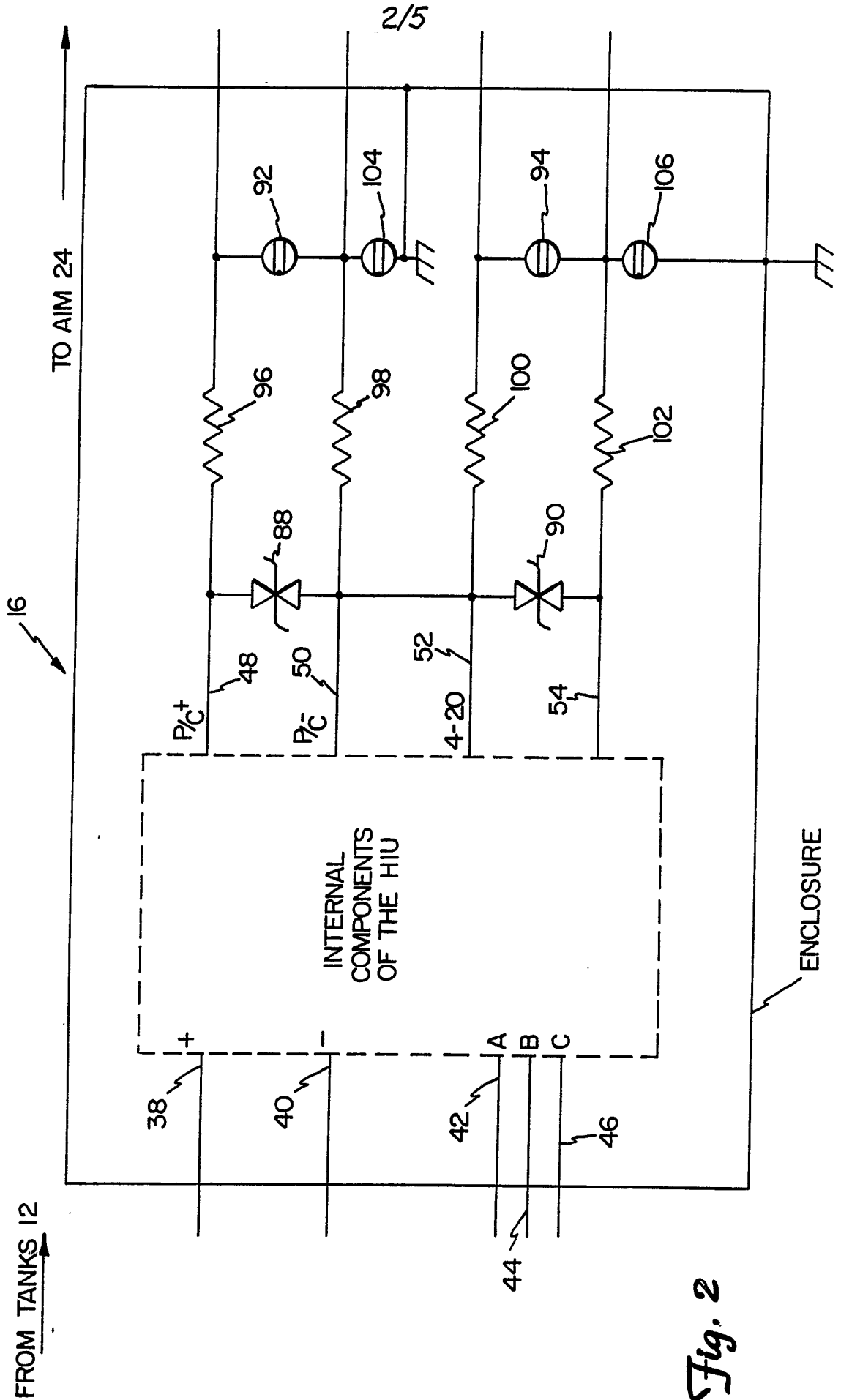


Fig. 2

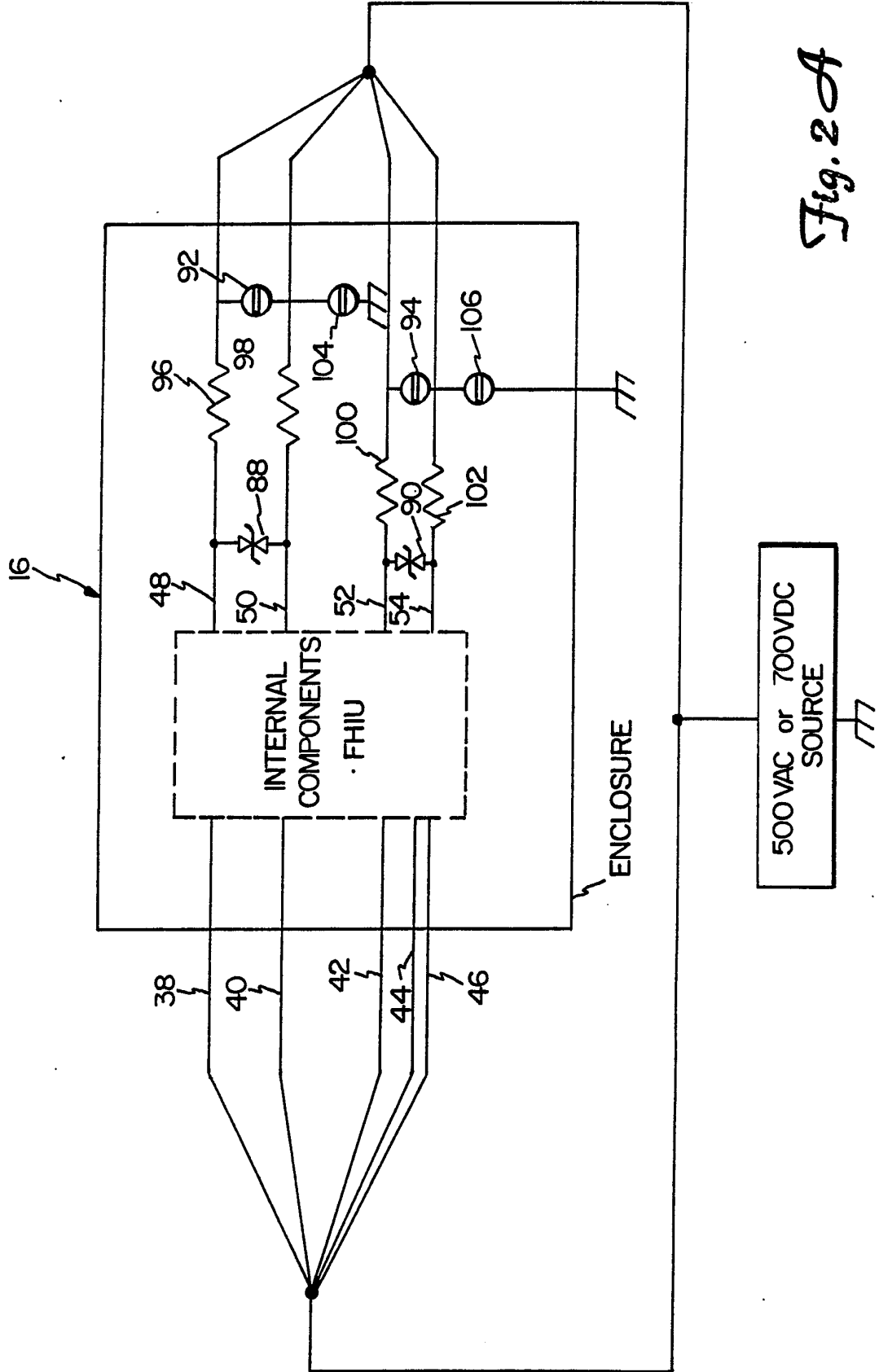


Fig. 2A

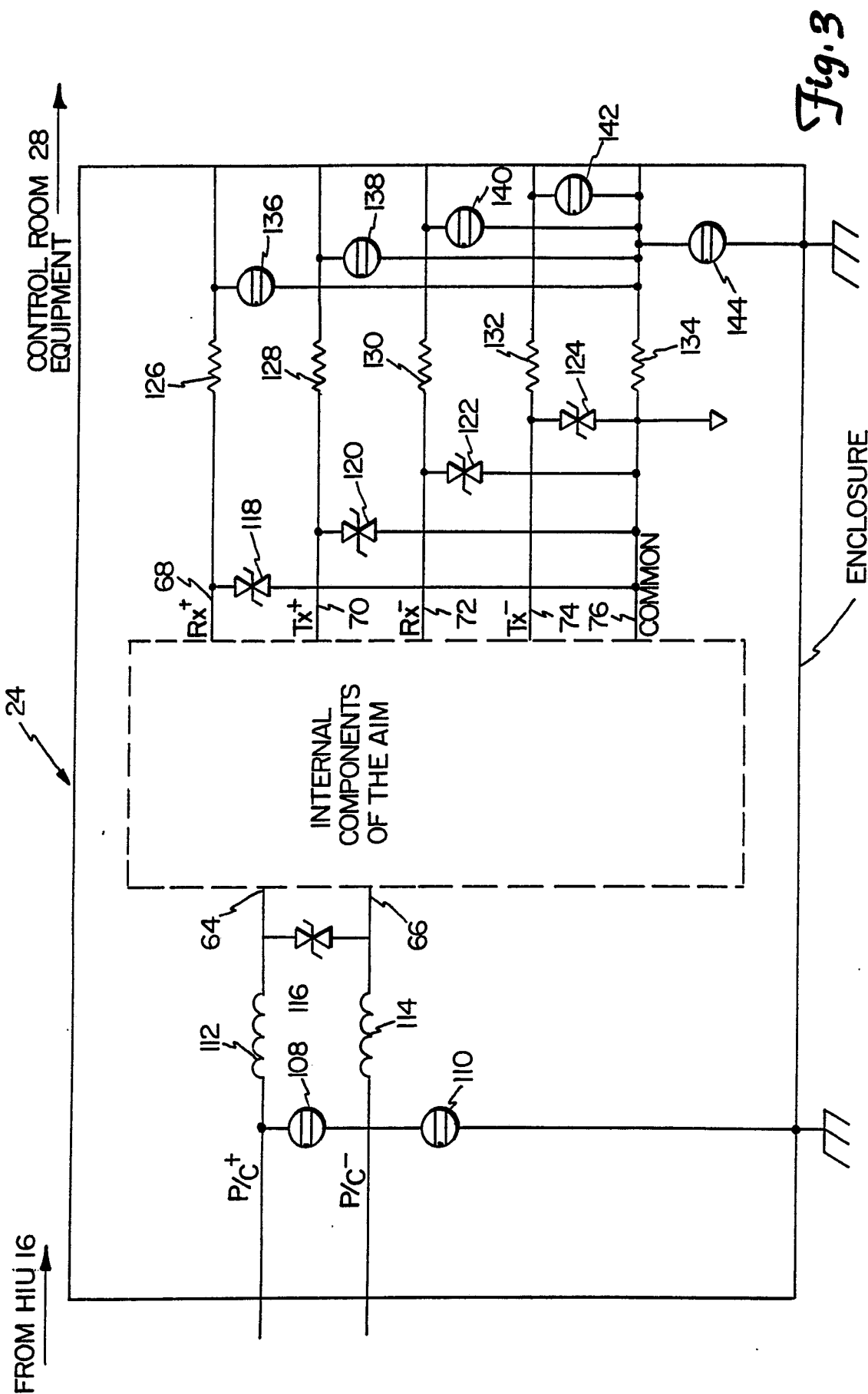


Fig. 3

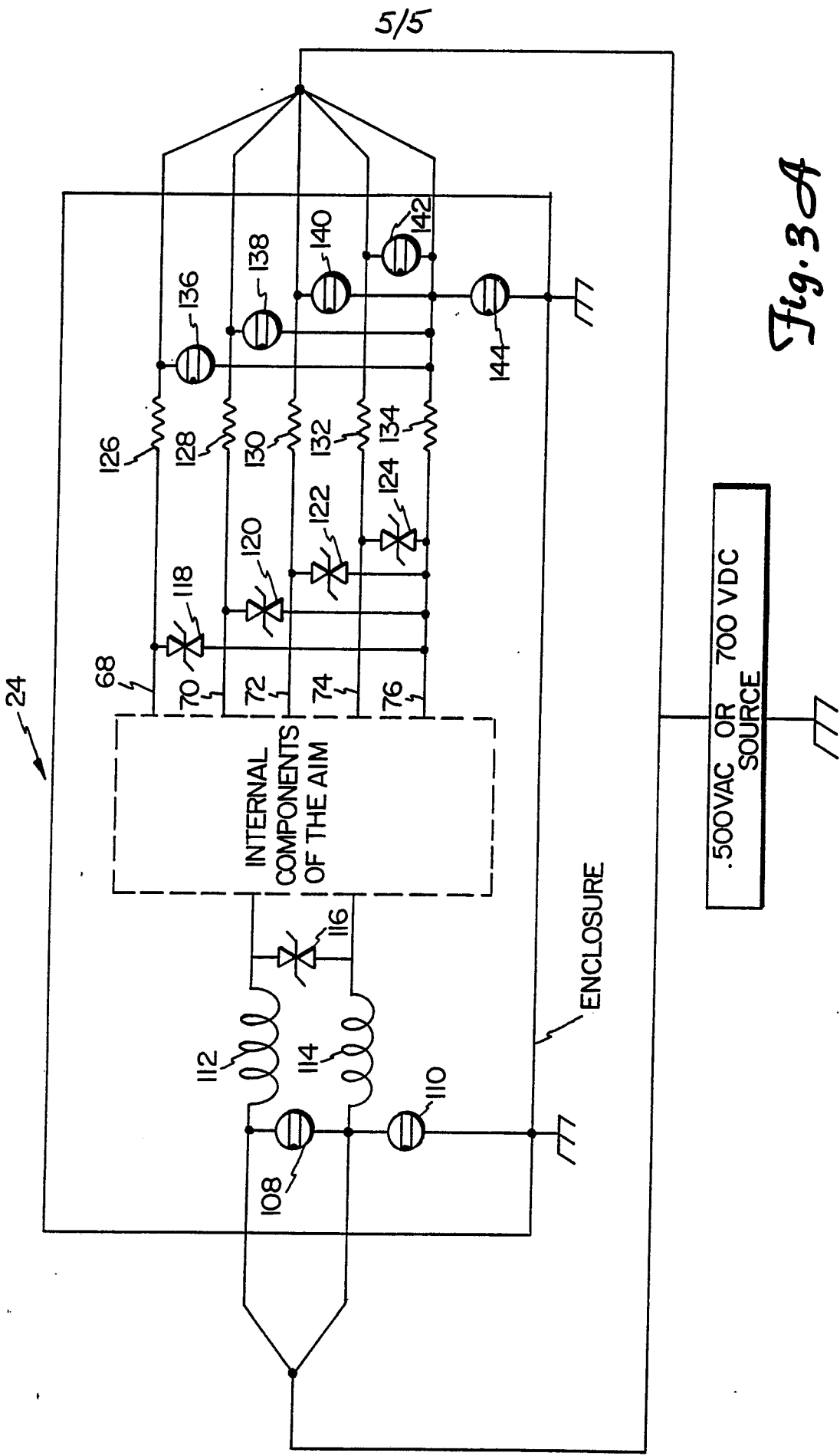


Fig. 3A

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US92/06595

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H02 H 9/00, 3/22, 1/00, 1/04, 3/22, 9/06  
US CL :361/56, 111, 117, 119

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 361/56, 111, 117, 119

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X/Y	US, A, 4,901,183 (Lee) 13 February 1990 (See Fig. 1, col. 4, line 594).	<u>1,2,10,11,13</u> 3-8,9,12,14
Y	US, A, 4,999,729 (Stifter) 12 March 1991 (See Col. 2, line 14-15).	3-8,14
Y	US, A, 4,758,920 (Mc Cartney) 19 July 1988 (See fig. 1).	9,12

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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