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(54) **Electrical connector shielded against EMP and EMI energy**

(57) A drawback of electrical connectors shielded against EMP energy is their limited capacity to suppress electromagnetic pulses because gas discharge tubes used in such connectors are not fast enough. Very fast suppression is achieved with an electrical connector comprising a cylindrical housing having an axially extending passageway there through. A circular metallic cross-plate divides the passageway into two compartments; the front-end compartment includes EMP protection means, which comprise a gas filled protector and at least two suppressing elements having suppression time shorter than that of the gas filled tube. The rear end compartment includes a filter means. EMP protection means residing in the front-end compartment consist of a discharge element such as a gas filled discharge tube having turn-on time T , a first suppressing element having suppression time T_1 less than T , and a second suppressing element having two-step suppression time, namely T_2 less than T and T_3 less than T but greater than T_2 so that $T_2 < T_3 < T$. When a transient voltage surge arrives, the first and the second suppressing elements are suppressing the pulse during the period that the gas discharge tube needs to turn on.

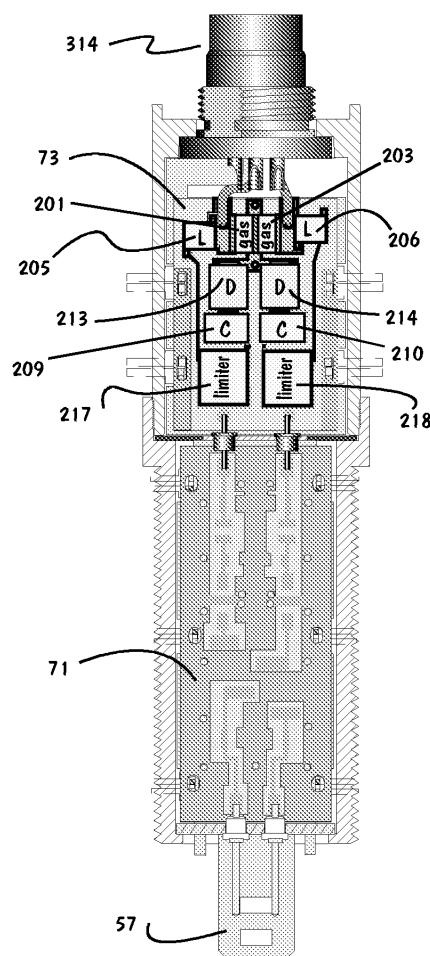


FIG. 8

Description

Field of the invention

[0001] This invention relates to electrical lead-through and, more particularly, to an electrical lead-through connector providing protection against electromagnetic interferences and especially against power surges owing to electrostatic discharges of electromagnetic pulses.

Background of the invention

[0002] Electromagnetic interference (EMI) entering a system may cause disruptions in the electrical circuitry of the system. External EMI energy is an undesired conducted or radiated electrical disturbance that can occur anywhere in the electromagnetic spectrum. Particularly lead-through of cables and conductors are vulnerable because lead-through may act as transmission path of EMI energy. Therefore, if good protection against EMI is needed special electrical lead-through connectors having substantial shielding effectiveness against EMI must be used. There are a lot of such connectors available in the market and the basic idea therein is to lead external disturbances to a grounded metallic housing that acts as a shield against external disturbances. Various arrangements have been used to conduct electrical signals from outer pins to inner pins of a connector and vice versa.

[0003] Lightning and nuclear explosions result in a sharp pulse of radio frequency electromagnetic radiation. An electromagnetic pulse (EMP) caused by a nuclear explosion has a rise time on the order of 10 nanoseconds (ns). The intense electric and magnetic fields that electromagnetic pulse (EMP) creates can damage unprotected electrical and electronic equipment over a wide area.

[0004] Local area networks or wide area networks are data transmission systems for transmitting information between a master unit and remote units of a subordinated system or between subordinated units. In such systems information is transmitted among the units wherein a plurality of transmission lines between the units is needed. Consequently, the amount of lead-through connectors for cables in the system is high. To protect sensitive circuitry of the units against EMP and EMI energy the cabinets for the units are made of metal. However, a weak point of the cabinets is lead-throughs because lead-through connectors serve as pathways for EMP. Protection against transient voltage surges caused by EMP is absolutely necessary in certain deployable networks like military networks and networks to be erected in crisis areas.

[0005] Various solutions to shield connectors against EMP pulses are known in the art. For example, US 4330166, Cooper et. al, describes an improvement to an electrical connector intended to use at range 100 MHz to about 1 Ghz. The improvement comprises a conductive spring washer made of beryllium copper alloy that is seated in the plug portion of the connector. When EMP

pulse arrives, the washer is compressed which in turn makes a conductive path that diverts the pulse to ground. A drawback of this arrangement is that due to large voltage spike and very fast rise time of EMP pulse it fails to divert the pulse fast enough, which results high currents and voltages in the circuitry. This is detrimental to most electronic devices.

[0006] Applying gas filled overvoltage protectors to surge transient pulses is also known in the art. The breakdown voltage of such a gas discharge tube is relatively high and reasonable protection can be achieved by installing a gas discharge tube between the line and the ground.

[0007] A drawback of the overvoltage protectors filled with gas is their self-capacitance that limits their use to applications typically up to 2,5 GHz. However, operation frequency may be as high as 18 GHz if resonant cavities that separate the gas tube from the inner coaxial line are used as US 5978199, German et al, teaches.

[0008] Another drawback is bound up with the breakdown voltage of the gas filled protector. Namely, when EMP arrives it takes a certain time before gas discharge takes place in the tube. There are implementations, especially military ones, where specifications require shorter times that it is possible to obtain with gas filled protectors.

[0009] Therefore, there is a need for an electrical connector that more efficient than the prior-art connectors prevents propagation of EMP energy from an external cable into a cabinet surrounding electrical circuitry therein.

Brief summary of the invention

[0010] The disadvantage of the prior art connectors are reduced or eliminated by use of a multi-pin electrical connector in the form of a cylindrical housing with couplings at both ends as a plug connector for a multi-conductor cable at one end and a plurality of electrical terminals at the other end. The cylindrical conductive housing has an axially extending passageway therethrough and is provided with a circular metallic cross-plate dividing the passageway into two compartments. The front-end compartment, with which the plug connector is engaged, includes EMP protection means comprising a gas filled over-voltage protector and at least one suppressing element having suppression time shorter than turn-on time of the gas filled tube. The rear end compartment, with which the electrical terminals are engaged, includes a filter means in electrical engagement with output electrical terminal on one hand and with EMP protection means in the front-end compartment on the other. The circular cross-plate forms a part of EMI shield for circuitry in a cabinet, the other parts being formed by the cylindrical housing and the metallic casing of the cabinet.

[0011] Optionally, both compartments are divided into two sub-compartments with a longitudinal metallic plate extending axially throughout the passageway and so di-

viding the circular metallic cross-plate into two halves. The longitudinal metallic plate serves as a base plate for supporting circuit boards fixed on both sides of the base plate. Thus, said longitudinal metallic plate also serves as a shield against electric interference owing to the electric field caused by currents on the circuit board on the opposite side of the base plate. Further, the base plate separates incoming and outgoing signal paths from each other wherein each signal path is provided with its own suppression means and filter means.

[0012] Suppression means residing in the front-end compartment consist of a gas filled discharge tube having turn-on time T , a first suppressing element having suppression time T_1 less than T , and a second suppressing element having two-step suppression time, namely T_2 less than T , and T_3 less than T but greater than T_2 so that $T_2 < T_3 < T$.

[0013] Now, when a transient voltage surge arrives from a cable via the plug connector to the front-end compartment, the gas filled discharge tube should immediately divert it to ground. However, because the rise time of EMP is around 10 nanoseconds (ns) but the time required to cause gas discharge in the tube is longer, the amplitude of the transient pulse would have enough time to rise to an amplitude level that can damage circuitry of an electronics module with which the connector is used. This is prevented by the additional suppressing elements having shorter suppression times than that of the gas filled discharge tube.

[0014] The first suppressing element is extremely fast and immediately upon arriving the transient voltage it starts to retard the rise of the pulse.

[0015] Nevertheless, after a very short time the level of the pulse at the output of the first suppressing element is rising rapidly. Now, the second suppressing element having somewhat longer suppression time than that of the first suppressing element activates. It takes the suppression task from the first element and start to absorb energy of the pulse.

[0016] The time that said suppressing elements are using to suppress the transient pulse is shorter than the time the gas discharge tube needs to turn on. Thus, after its ignition the gas discharge tube diverts the transient pulse to ground.

[0017] Optionally, the suppression elements may include a transient blocking unit that acts as DC current limiter so limiting the DC current to a certain level, 250 mA for example.

Brief description of the drawings

[0018] The invention will now be described, by way of example, with reference to the following drawings, in which

Fig. 1 is a schematic diagram of an electrical connector,

Fig. 2 is a schematic diagram of an electrical connec-

tor having four transmission paths,

Fig. 3 shows an outer side view of the connector,

Fig. 4 depicts a half sectional view of the connector housing,

5 Fig. 5 shows a base plate,

Fig. 6 shows a side view of the base plate,

Fig. 7 is a sectional view of the connector with incorporated base plate,

10 Fig. 8 is a sectional view of the assembled connector, and

Fig. 9 shows current curves measured at the input terminal and the output terminal of the connector.

Detailed description

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[0019] The electrical connector whose simplified schematic diagram is shown in **Fig. 1** is intended for connecting circuitry inside a metallic cabinet via a cable with a remote unit. The connector comprises a metallic cylindrical housing **10** with a plug connector **12** for a multi-conductor cable (not shown) at one end and a plurality of electrical terminals to be connected with wiring of electrical circuitry inside the cabinet at the other end. The interior of the cylindrical conductive housing forms an axially extending passageway that circular metallic cross-plate **11** divides into two compartments **101** and **102**. The front-end compartment **101** includes electromagnetic pulse (EMP) shielding means comprising gas filled protector **1** and first suppressing element **2** and second suppressing **4** having suppression time shorter than that of gas filled tube **1**. The rear end compartment **102** includes filter means **6** in electrical engagement with electrical terminals **13**. Thus, electrical components and circuits in both compartments are fully surrounded by the metallic housing and circular metallic cross-plate **11** between the compartments, the latter acting as an EMI shield protecting circuitry in the cabinet against external electromagnetic interference.

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[0020] Optionally, current limiter **5** is also located in the front-end compartment in order to limit DC current to the cable filter means.

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[0021] Suppression times of electromagnetic pulse (EMP) shielding means in the front-end compartment are arranged as follows:

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[0022] As the impulse energy of EMP reaches the connector, the gas filled protector **1** needs time T to turn on and to divert energy to ground. This turn-on time is too long for preventing damages in circuitry and therefore first suppressing element **2** connected in series with the transmission line **3** starts to suppress much faster, practically immediately, but it is effective only for limited time T_1 that is termed here as a suppression time. Thus, the suppression time $T_1 < T$. Hereafter, "a suppression time" means that short instant when an element actively is suppressing a transient pulse.

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[0023] Second suppressing element **4** that affects in two phases and consequently has two suppression times T_2 and T_3 , is connected in series between the transmis-

sion line and ground. Said suppression times are higher than the suppression time of the first suppressing element. One suppression time of the second suppression element **4** is T_2 so that $T_1 < T_2 < T$. Another suppression time is T_3 so that $T_1 < T_3 < T_2$. Finally, optional current limiter **5** needs also a certain time for starting to limit DC current but anyway the time is shorter than the turn-on time of the gas tube.

[0024] In other words, by selecting components properly for building suppressing elements having above-mentioned suppression times, a great deal of energy of the incoming transient pulse may be absorbed so that the remaining part will not damage electronic circuitry in the cabinet.

[0025] The operation of the connector is now rather easy to understand. As a transient pulse arrives, the first suppressing element having the shortest suppression time acts first and starts delay the rise of the pulse that appears after that element. After a very short time a part of the second suppressing element **4** activates which in turn causes that the second suppressing element starts to absorb energy of the transient pulse. At the same time current limiter **5** is limiting the DC current that is progressing to filtering circuitry **6**. Thus, during the short period $0-T$ when the gas filled tube **1** has not yet turned on, the suppressing elements are cutting the incoming transient pulse (EMP) and lowering its energy to a level that brings no harm to the electronic circuitry in the cabinet. Finally, after time T , the gas tube ignites and starts to divert energy of the transient pulse to ground.

[0026] Fig. 2 is a schematic diagram of an electrical connector having four transmission lines through it, i.e. each of four signal pins **21a-24a** of the cable plug coupling attached to the front end of the electrical connector is wired to a respective pin **21b-24b** of the coupling residing at the rear end of the connector. Each transmission path comprises EMP suppressing elements as shown in Fig. 1. Thus, the front-end compartment of the connector includes four gas discharge tubes **201-204**, four current limiters **217-220**, and suppressing elements.

[0027] The first suppressing element in each signal path is the series-coupled coil **205-208**. So, as a transient voltage arrives the voltage after the coils starts immediately to rise exponentially depending on an inductance value of the coil and an impedance value towards the DC current limiter. This is well known in the art but it is worth noting that using a series inductor the transient voltage is transformed to a voltage having a certain rising rate.

[0028] The second suppressing element in each signal path comprises of capacitor **209-212** and diode **213-216** coupled in series between the signal path and ground. Therefore, the second suppressing element owns two suppression times; T_3 for the diode and T_2 for the capacitor. The transient voltage that the coil is transforming to an exponentially rising voltage affects on the capacitor but due to not-conductive diode **213-216** the capacitor is not charging.

[0029] A diode has a certain rearward voltage value

so that after time T_3 when the voltage over the diode exceeds that value the diode becomes conductive. Therefore, the diode is the next element that becomes active after the transient pulse has arrived. In other words, the voltage between the capacitor and the diode rises exponentially depending on the first suppressing element i.e. on an inductance value of the coil. As the voltage reaches the threshold value of the diode the voltage over the diode drops which in turn causes that the capacitor is charged. Charging of the capacitor takes current, which means that a piece of energy of the transient pulse is absorbed to ground.

[0030] DC current limiters **217-220** limit the through-going current further to a certain value, 250 mA for example.

[0031] Next, a practical implementation of the connector according to the present invention will be discussed. The implementation comprises of a metallic housing, a base plate supporting circuit boards with electrical components thereon, and coupling means for coupling a cable to the connector on one hand and to the circuitry inside a cabinet on the other hand

[0032] Fig. 3 presents an outer side view of the connector. It comprises a two-part cylindrical metallic housing **31**, both parts having the form of a tube. A nut **312** with internal threads for receiving a threaded end of the second part **311** has been formed at one end of the first part **310**. Nut **313** is intended for fixing the connector to a hole in a cabinet wall. Plug connector **314** with contact pins for receiving a plug of a multi-conductor cable is screwed into the internal thread that is provided at the front-end face of the part **311**.

[0033] Fig. 4 depicts a half section view of the connector housing of Fig. 1. As shown, the hollow interior of the tubular housing forms an axially extending passageway through the connector. Into the passageway it is inserted metallic base plate **51** that is more detailed shown in Figs. 5 and 6. The metallic base plate extends lengthwise through the whole connector and the width of the base plate is around the diameter of the passageway. The metallic base, whose top-view is seen in Fig. 5, is intended to support circuit boards fixed on both sides of the plate. In addition, circular metallic cross plate **52** is fixed perpendicular to the base plate, wherein, after the base plate has been inserted into the passageway, the circular metallic plate divides the passageway into two compartments. Hence, the circular metallic cross plate acts as EMI shield between the compartments. Further, the base plate also divides both compartments into two sub-compartments.

[0034] Fig. 5 is a top view of the metallic base plate. **51**. The plate is assembled from three parts; the circular cross plate **52** and two half-sides **51a** and **51b**, which are joined symmetrically to the opposite sides of the circular cross plate. In edges of the half-sides there are notches **54** that come about when a pair of strips that are cut at the longitudinal edges of the base plate are bent upward and downward. Protrusion **57** that in the assem-

bled connector extends from its rear end serves for joining a ground lead to it.

[0035] Fig. 6 is a side view of the metallic base plate. Circular cross plate 52 that forms EMI shield as well as fixing clamps 55/56 for soldering circuit boards to the base plate are clearly visible.

[0036] Thus, the connector housing of Figs. 3-4 and the base plate of Figs. 5-6 inserted to the passageway of the housing form the mechanical framework of the electrical connector of the present invention.

[0037] Fig. 7 is a sectional view of the electrical connector provided with the base plate supporting circuit boards inserted therein. As seen, circular cross plate 52 of the base plate divides the passageway inside the connector housing into front-end compartment 41 and rear end compartment 42, and base plate halves 51a and 51b further divide said compartments into two sub-compartments 41a, 41b and 42a, 42b, wherein each sub-compartment is surrounded by a metallic wall.

[0038] Base plate half 51a in the front-end compartment 41 supports circuit boards 73 and 74, whereas base plate half 51b in the rear end compartment 42 supports circuit boards 71 and 72. Therefore, each circuit board is well protected against interferences by metallic layers surrounding the circuit board. The pins of plug connector 31 for a multi-conductor cable are wired to circuit boards 73 and 74 whereas pins 53 for wiring the connector to circuitry in a cabinet are wired to circuit boards in the rear end compartment. In addition, wires that go through holes (not shown) made in the circular plate 52 interconnect circuit boards 71 and 73. The same applies respectively to circuit boards 72, 74. The electrical components attached on the circuit board are arranged so that EMP suppression elements reside in the front-end compartment whereas "conventional" filtering means reside in the rear end compartment. EMI shield 52 separates the compartments.

[0039] Fig. 7 corresponds to fig. 2 in the sense that electronic components fixed on the circuit boards 71 and 73 are the circuit elements of the two upper branches in fig. 2 whereas the components fixed on the circuit boards 72 and 74 are the circuit elements of the two lower branches in fig. 2. Thus, the connector includes four separate signal paths; one pair residing in one sub-compartment and another pair in another sub-compartment. The signal path pair residing in the same sub-compartment may be used for conveying digital signals whereas another signal path pair residing in the neighboring sub-compartment may be used for conveying analog signals.

[0040] Fig. 8 is a sectional view of the electrical connector illustrating actual suppression elements and their location in the connector. Reference numbers correspond to numbers in Fig. 2. Suppression elements are located on the circuit board in the front-side sub-compartment. As a transient pulse such as EMP arrives from the cable, it progresses to coils 205 and 206 that delay the rise of the pulse after the coils. Due to their tardiness the gas discharge tubes 201, 203 do not act yet. As the

voltage after the coils is rising, then after time T_3 the voltage between capacitor 209 and diode 213 (and capacitor 210 and diode 214 respectively) has reached the level when diodes become conductive whereupon capacitors will be charged. Charging capacitors consumes EMP energy long enough so that turn-on times of the gas discharge tubes have lapsed whereupon the tubes divert EMP energy to ground.

[0041] Ascribe to suppression elements and current limiters 217, 218 EMP energy progressing to filters on the rear end compartment is low enough so that after further filtering in filtering circuits (not shown) on the circuit board 71 the voltage and current at pins 53 are low and do not disturb circuitry connected to said pins.

[0042] Fig. 9 depicts curves obtained in a real measurement where EMP pulse according to a test standard has been applied to the connector. The current amplitude of the test pulse is 4 kA and the test standard requires that the maximum current measured at the output pins of the connector does not exceed 1 A.

[0043] Curve "Current In" represents the input current pulse whereas curve "Current Out" represents the current measured at the output pins. As the input pulse is rising very rapid the first and second suppressing elements of the invention operates as described previously. Thus, during the short period ΔT when the first and second suppressing elements actively influence to the pulse, the output current is rather low, only 0,4-0,6 A. Then after that period the gas discharge tube has turned on resulting in the output current of around 0,2 A. The practical measurements have proven that the electrical connector with the invented suppression means fulfills requirements of most strictly standards.

[0044] An artisan of the art naturally understands that other kind of components or circuits can replace the components of the first and the second suppression elements also. In addition, it has to be pointed out that in the previous example a cylindrical connector is described but it is clear that other modifications will also be apparent to those skilled in the art.

Claims

1. An electrical connector shielded against EMP and EMI energy, comprising
 - a cylindrical metallic housing (31) having a plug connector (314) at the front end and a plurality of terminal pins (53) at the rear end,
 - a passageway extending through said housing, wherein signal paths are formed by operatively connecting each pin of the plug connector with a respective terminal pin at the rear end, **characterized by**
 - a circular metallic cross-plate (52) dividing the passageway into a front-end compartment and a rear end compartment,
 - a filter means residing in the rear end compartment, said filter means being connected with the terminal

pins,

a EMP protection means residing in the front-end compartment and connected with the plug connector (314) and the filter means,

said EMP protection means in each signal path comprising:

a gas-filled discharge tube (1) connected between the signal path and the cylindrical metallic housing and having a turn-on time T ,
 a first suppressing element (2) connected in series with the signal path and having a suppression time T_1 less than the turn-on time T ,
 a second suppressing element (4) connected between the signal path and the cylindrical metallic housing (31) after the first suppressing element (2), and having a suppression time T_2 that is greater than the suppression time T_1 of the first suppressing element (2) but less than the turn-on time T ,

wherein the first suppressing element and the second suppressing element suppress energy of an incoming transient pulse to a non-damaging level prior to turning-on of the gas-filled discharge tube (1)

2. The electrical connector as in claim 1, **characterized in that** the first suppressing element (2) is a coil (201; 202; 203; 204), wherein the coil delays the rise of the transient pulse.
3. The electrical connector as in claim 1 or 2, **characterized in that** the second suppressing element (2) is comprised of a capacitor (209; 210; 211; 212) and a diode (213; 214; 215; 216) coupled in series, wherein after the delayed transient voltage between the capacitor and the diode has exceeded a threshold value of the diode the capacitor is charged and the second suppressing element absorbs energy of the transient pulse.
4. The electrical connector as in claim 1, **characterized in that** the EMP protection means in each signal path further comprise a DC current limiter (217; 218; 219; 220) for limiting a current to a predetermined output current.
5. The electrical connector as in claim 1, **characterized by** a longitudinal metallic plate (51) of the diameter of around the passageway in width extending axially throughout the passageway and so dividing the front-end compartment (41) and the rear end compartment (42) into two sub-compartments (41a, 41b and 42a, 42b).
6. The electrical connector as in claim 5, **characterized in that** each sub-compartment includes a circuit board (73; 74; 71; 72) fixed on the longitudinal me-

tallic plate (51), and discrete components of the EMP protection means and the filter means are fixed on said circuit boards.

7. The electrical connector as in claim 5, **characterized in that in that** the longitudinal metallic plate (51), the circular metallic cross plate (53), and the circuit boards (71, 72, 73, 74) with the components fixed thereon compose a single unit that is insertable into the passageway.
8. The electrical connector as in claim 7, **characterized in that** said single unit further comprises the plug connector (314) joined to the front end of the unit and the terminal pins (53) joined to the rear end of the unit.
9. The electrical connector as in claim 1 or 7, **characterized in that** the cylindrical metallic housing (31) is comprised of two tubular parts screwed together and the circular metallic plate (52) is clamped between the ends of the tubular parts facing each other.
10. The electrical connector as in claim 5 or 6, **characterized in that** signal paths transferring information in one direction reside in the adjacent sub-compartments (41a, 42a) on the same side of the a longitudinal metallic plate (51) and signal paths transferring information in opposite direction reside the adjacent sub-compartments (41b, 42b) on the opposite side of the a longitudinal metallic plate (51).

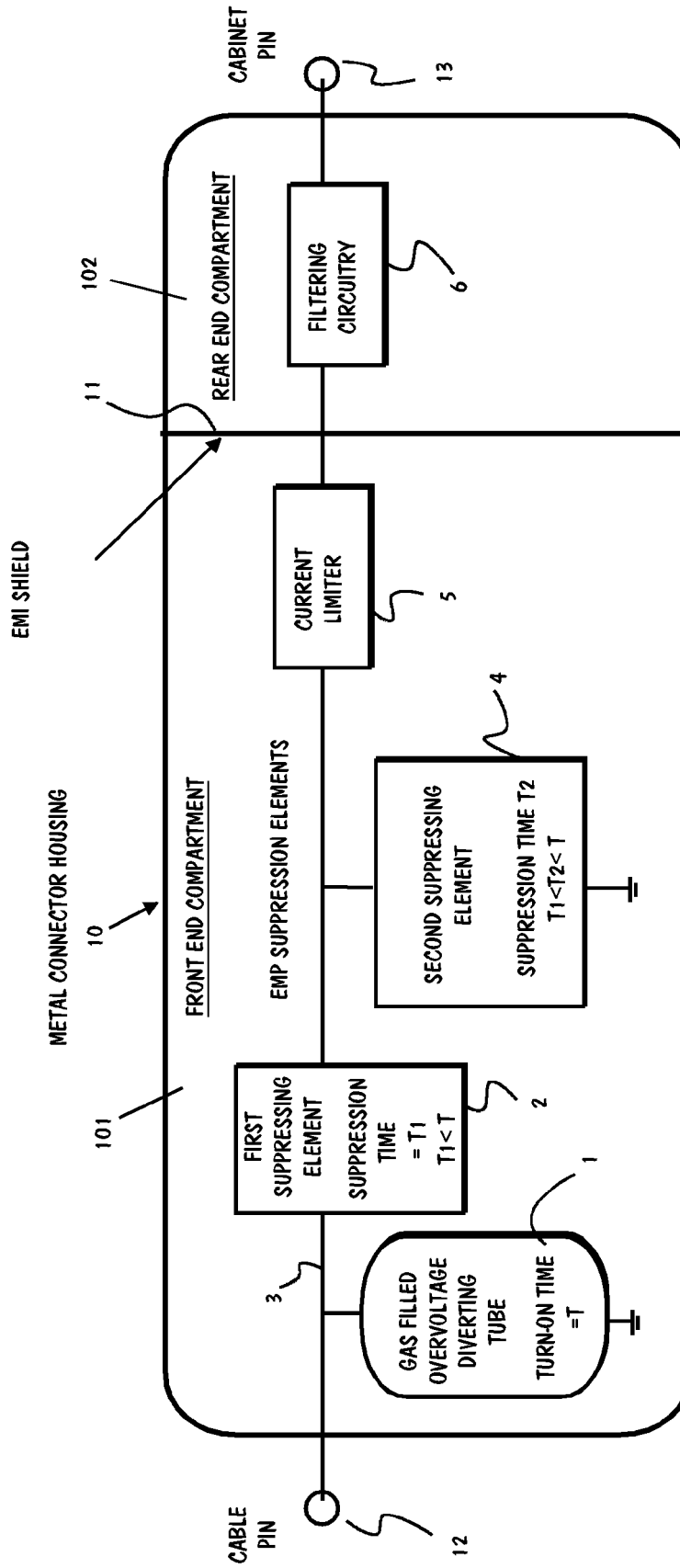


FIG. 1

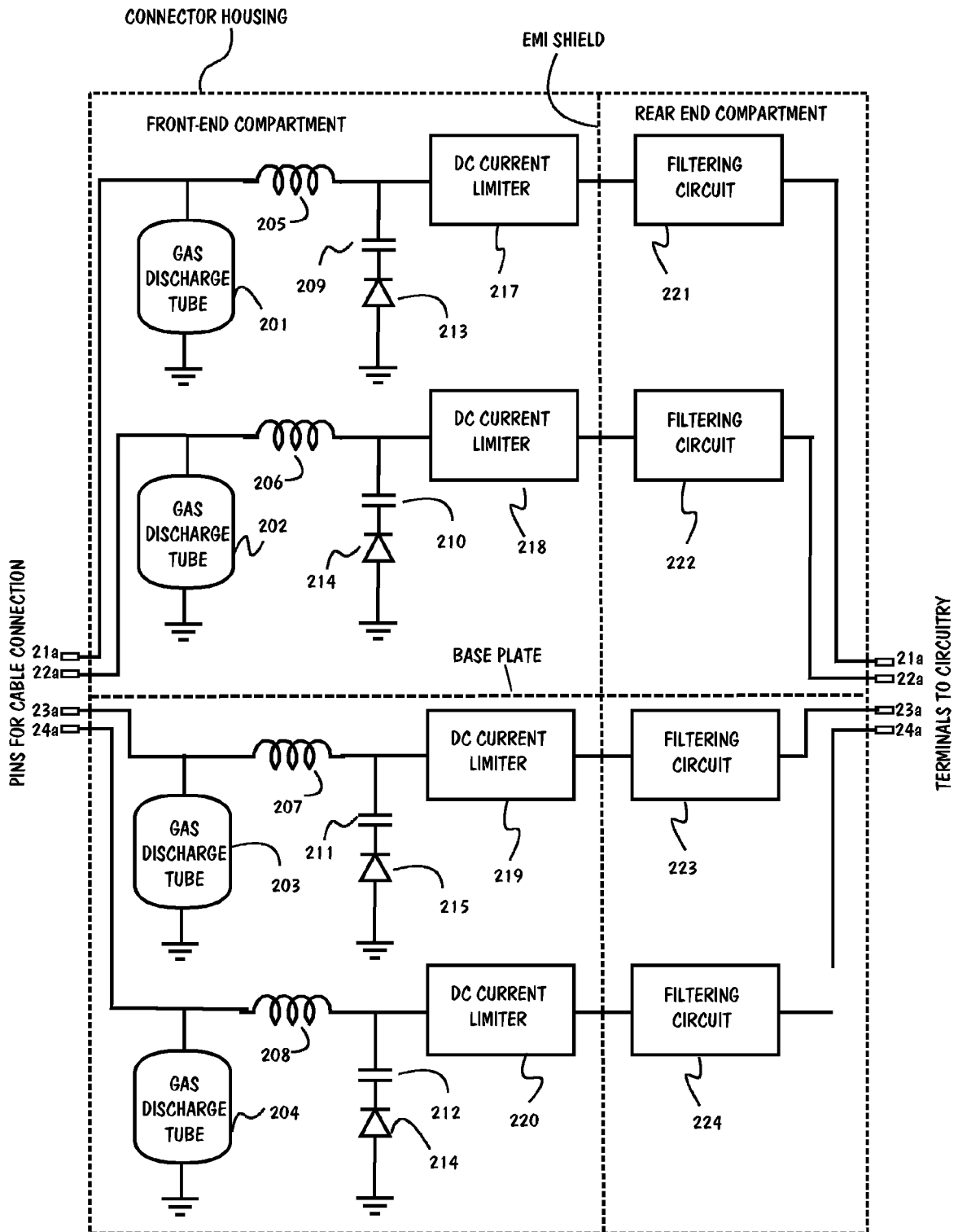


FIG. 2

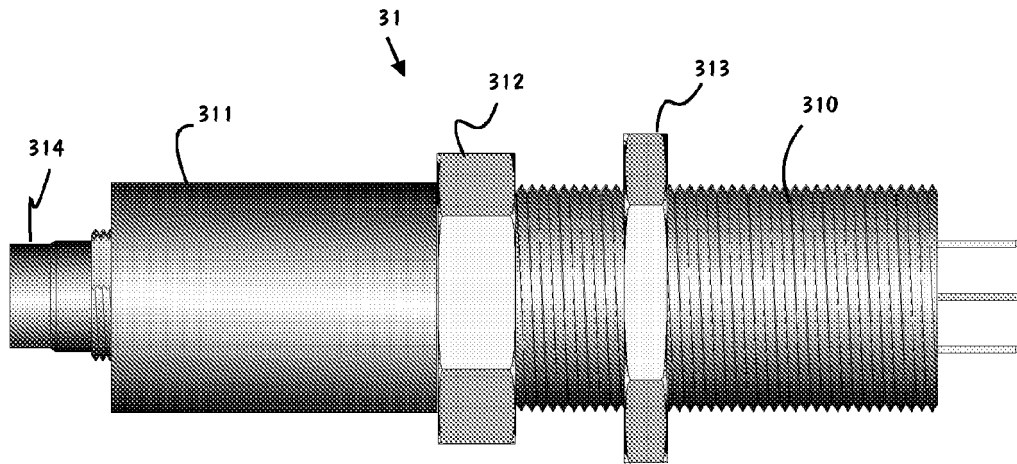


FIG. 3

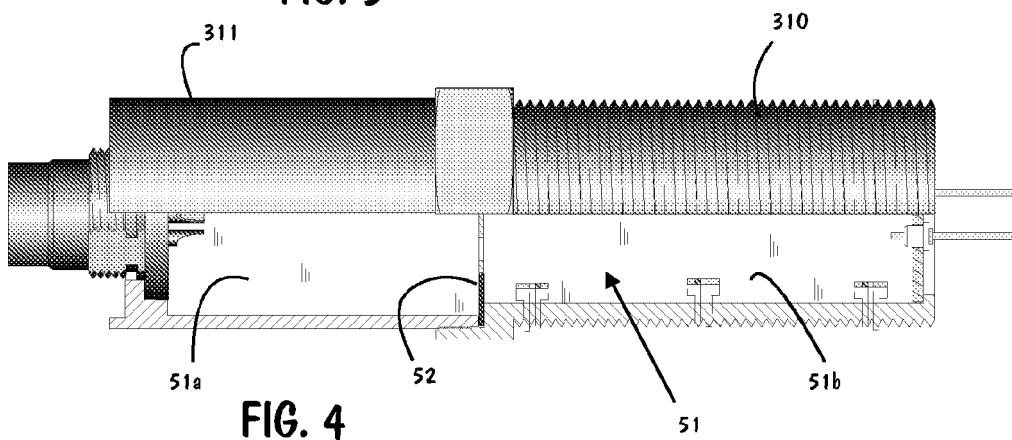


FIG. 4

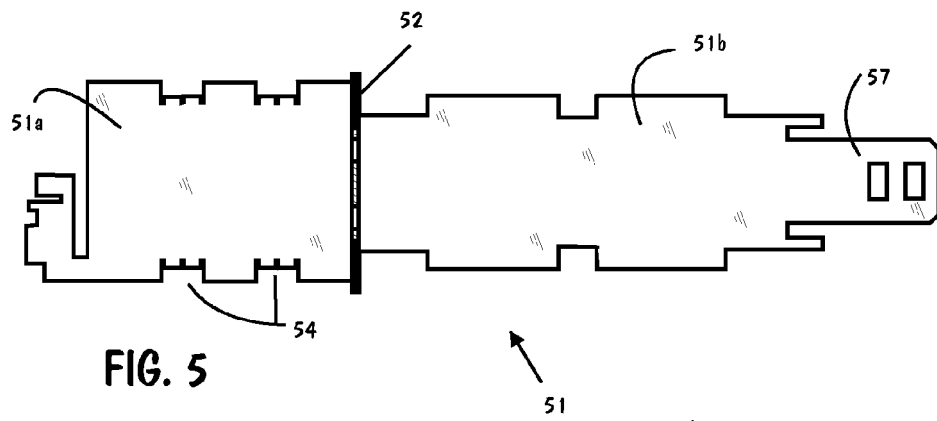


FIG. 5

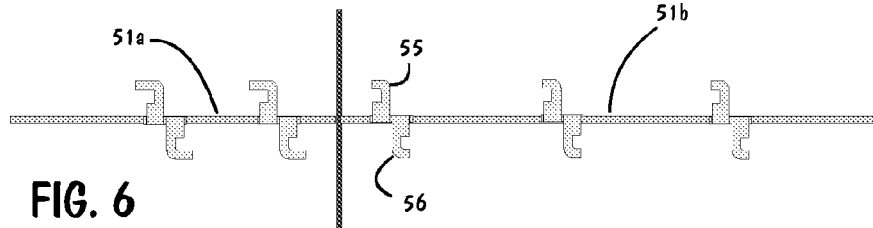


FIG. 6

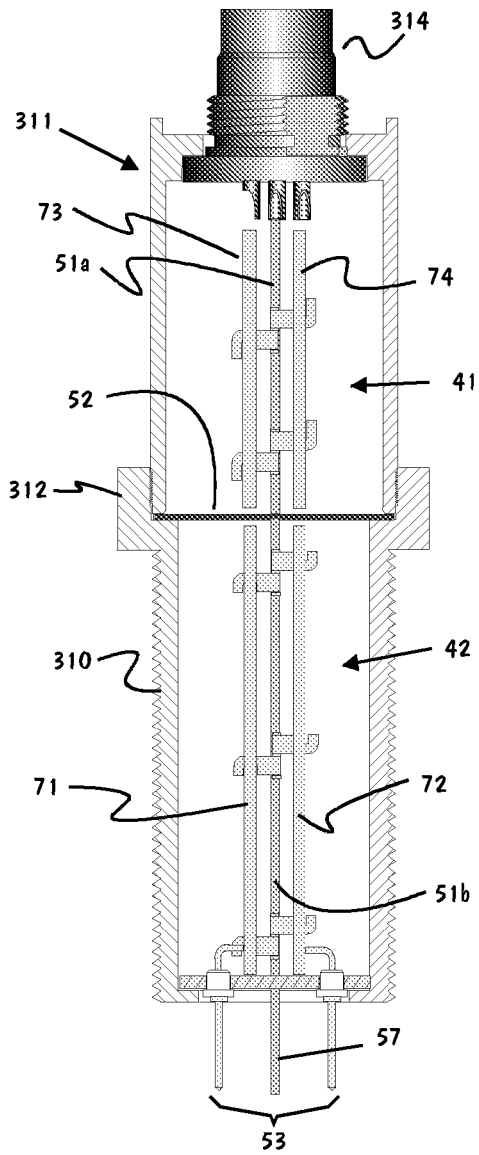


FIG. 7

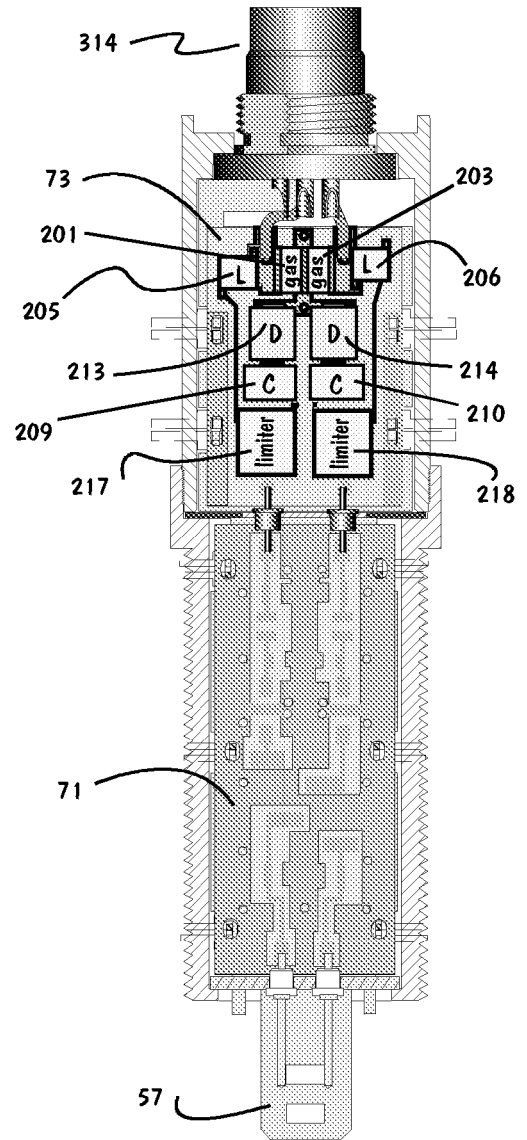


FIG. 8

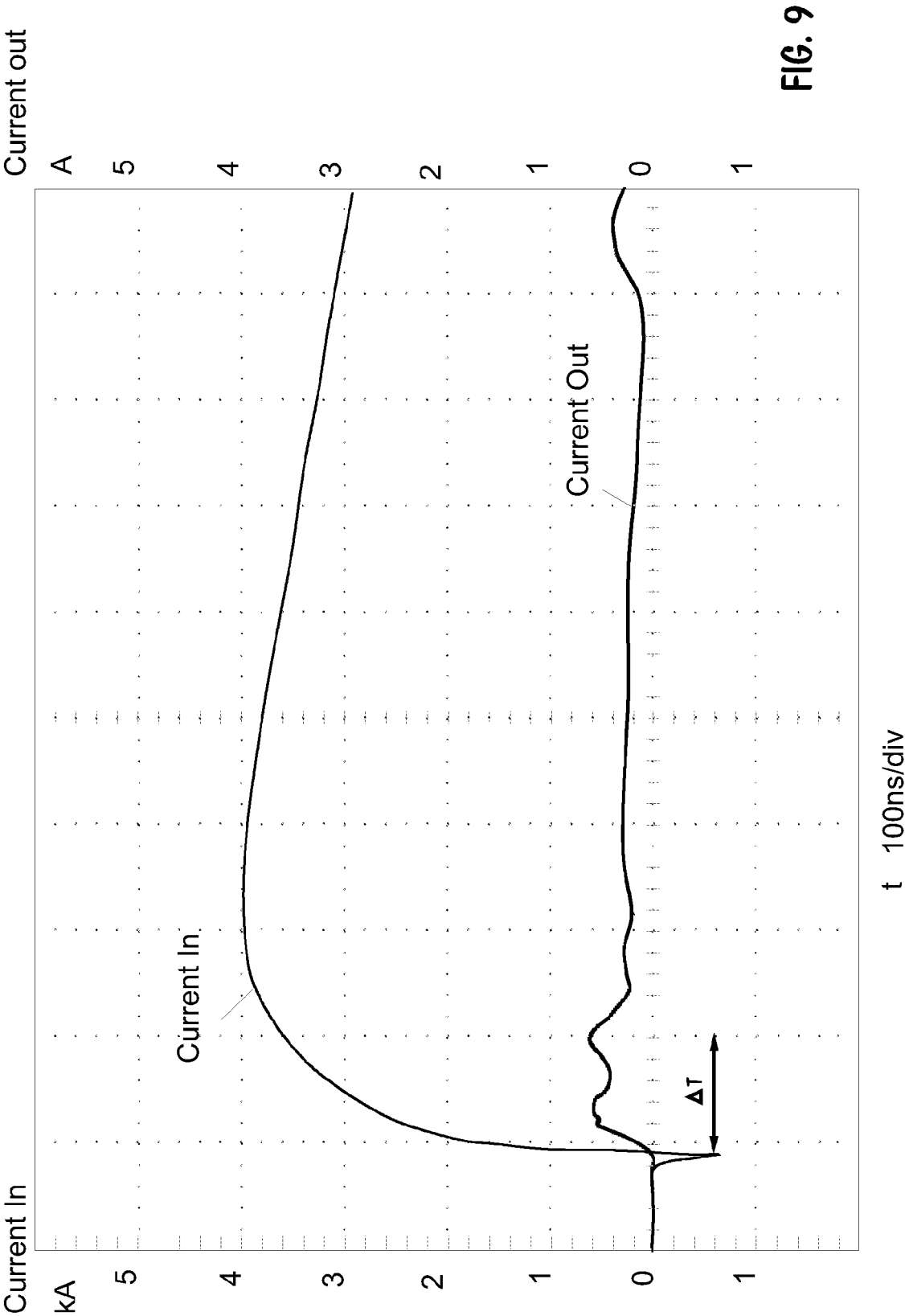


FIG. 9



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 39 7025

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 12 April 2007	Examiner Criqui, Jean-Jacques
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03 82 (P04C01)



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 06 39 7025

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 12 April 2007	Examiner Criqui, Jean-Jacques
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

4

EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 06 39 7025

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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