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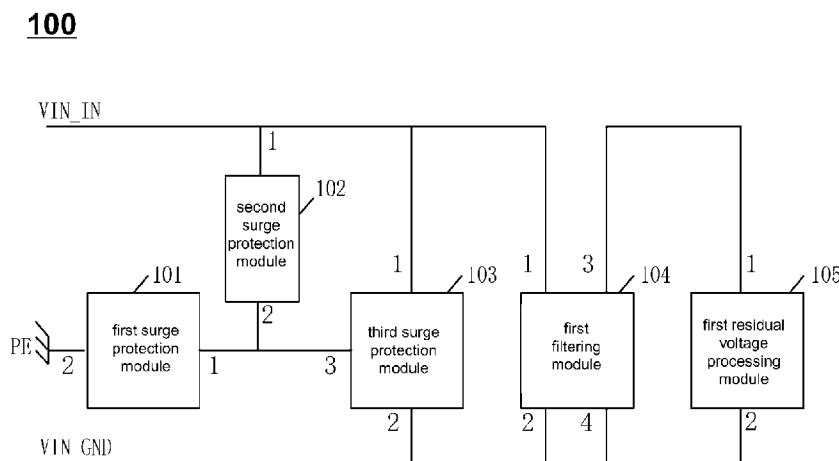


FIG. 1

(57) Abstract: A power surge protection circuit may include a first surge protection module, a second surge protection module, and a third surge protection module. The first surge protection module may be configured to cooperate with the second surge protection module to discharge the energy of a first surge generated between a positive input end of a power supply and a ground end and cooperate with the third surge protection module to discharge the energy of a second surge generated between a negative input end of the power supply and the ground end. The second surge protection module may be configured to cooperate with the third surge protection module to discharge the energy of a third surge generated between the positive input end of the power supply and the negative input end of the power supply and generate a residual voltage.

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POWER SURGE PROTECTION CIRCUITS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to Chinese application No. 202310513365.3, filed on May 06, 2023, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to the technical field of power protection, and in particular to power surge protection circuits.

BACKGROUND

[0003] Some terminal apparatuses used outdoors (e.g., a monitoring apparatus, etc.) may be subject to lightning surge hazards in environments such as thunderstorms. A surge refers to a signal that instantaneously appears as a peak beyond a stabilized value. The surge may be a spike pulse with a high rate of rise and short duration. Therefore, it is necessary to protect a terminal apparatus from being subjected to the possible surge. The current approaches to surge protection generally consist of adding a differential surge protection device between positive and negative power lines of a power supply of the terminal apparatus to discharge energy of the differential surge and adding a common mode surge protection device between the power lines and a ground line to discharge the energy of the common mode surge. However, the above approaches of surge protection require a large count of devices to be laid out on a printed circuit board (PCB), occupying a large board area and resulting in a small layout space.

SUMMARY

[0004] According to the embodiments of the present disclosure, a power surge protection circuit may be provided. The power surge protection circuit may include a first surge protection module, a second surge protection module, a third surge protection module, a first filtering module, and a first residual voltage processing module. The first surge protection module may be configured to cooperate with the second surge protection module to discharge an energy of a first surge generated between a positive input end of a power supply and a ground end, and cooperate with the third surge protection module to discharge an energy of a second surge generated between a negative input end of the power supply and the ground end. The second surge protection module may be configured to cooperate with the third surge protection module to discharge an energy of a third surge generated between the positive input end of the power supply and the negative input end of the power supply and generate a residual voltage. The first filtering module may be configured to filter out a noise generated by the power surge protection circuit when discharging the energy of the third surge or the energy of the first surge. The first residual voltage processing module may be configured to reduce the residual voltage.

[0005] In some embodiments, a first end of the third surge protection module may be connected with the positive input end of the power supply and a first end of the second surge protection module,

respectively. A second end of the third surge protection module may be connected with the negative input end of the power supply, a third end of the third surge protection module may be connected with a second end of the second surge protection module and a first end of the first surge protection module, respectively. A second end of the first surge protection module may be connected with the ground end. The first surge protection module may be configured to conduct a path between the first end of the second surge protection module and the second end of the first surge protection module when the first surge is generated, and may conduct a path between the second end of the third surge protection module and the second end of the first surge protection module when the second surge is generated to discharge the energies of the first surge and the second surge. The second surge protection module may be configured to conduct a path between the first end of the second surge protection module and the second end of the third surge protection module to discharge the energy of the third surge when the third surge is generated.

[0006] In some embodiments, the second surge protection module may include a first gas discharge tube and a first capacitor, and the first gas discharge tube and the first capacitor may be connected in parallel; and the third surge protection module may include a plurality of second gas discharge tubes and a plurality of second capacitors, the plurality of second gas discharge tubes may be connected in series, an end of the plurality of second capacitors may be connected with nodes of the plurality of second gas discharge tubes connected in series, respectively, and each of the nodes connects two adjacent gas second discharge tubes of the plurality of second gas discharge tubes and a count of the plurality of second gas discharge tubes may be greater than or equal to two, a difference between a count of the plurality of second capacitors and the count of the plurality of second gas discharge tubes may be equal to 1.

[0007] In some embodiments, a first end of the first capacitor and the first gas discharge tube may be determined as the first end of the second surge protection module, and a second end of the first gas discharge tube and the first capacitor may be determined as the second end of the second surge protection module. The second gas discharge tubes may be connected in series between the second end of the second surge protection module and the negative input end of the power supply, an end of a second gas discharge tube connected with the second end of the second surge protection module may be determined as the third end of the third surge protection module, an end of the second gas discharge tubes connected with the negative input end of the power supply may be determined as the second end of the third surge protection module, a first end of the second capacitors may be determined as the first end of the third surge protection module, and a second end of the second capacitors may be connected with the nodes, respectively.

[0008] In some embodiments, the second surge protection module may include a plurality of first gas discharge tubes and a plurality of first capacitors, the plurality of first gas discharge tubes may be connected in series, an end of the plurality of first capacitors may be connected with nodes of the a plurality of first gas discharge tubes, respectively, and each of the nodes may connect two adjacent first gas discharge tubes of the plurality of first gas discharge tubes, and a count of the plurality of first gas discharge tubes may be greater than or equal to two, a difference between a count of the plurality of

first capacitors and the count of the plurality of second gas discharge tubes may be equal to 1. The third surge protection module may include a second gas discharge tube and a second capacitor, and the second gas discharge tube and the second capacitor may be connected in parallel.

[0009] In some embodiments, the third gas discharge tubes may be connected in series between the positive input end of the power supply and the third end of the third surge protection module, an end of a first gas discharge tube connected with the third end of the third surge protection module may be determined as the second end of the second surge protection module, an end of the first gas discharge tubes connected with the positive input end of the power supply and the end of the second capacitors connected with the positive input end of the power supply may be determined as the first end of the second surge protection module. The end of the first capacitors connected with the positive input end of the power supply may be the first end of the first capacitors, and the second end of the first capacitors may be connected with the nodes, respectively. An end of the third surge protection module where the second gas discharge tube and the second capacitor may be connected may be determined as the third end of the third surge protection module, wherein the first end of the second gas discharge tube may be connected with the second end of the second capacitor, a second end of the gas discharge tube may be determined as the second end of the third surge protection module, and the first end of the second capacitors may be determined as the first end of the third surge protection module.

[0010] In some embodiments, the first surge protection module may include a first varistor. An end of a gas discharge tube connected with the positive input end of the power supply may be connected with a first end of the first varistor, and a second end of the first varistor may be connected with the ground end.

[0011] In some embodiments, the first surge protection module further may include a second varistor. An end of the gas discharge tube connected with the negative input end of the power supply may be connected with a first end of the second varistor, and a second end of the second varistor may be connected with the ground end.

[0012] In some embodiments, the first surge protection module may include a first varistor. An end of the gas discharge tube connected with the negative input end of the power supply may be connected with the first end of the first varistor, and the second end of the first varistor may be connected with the ground end.

[0013] In some embodiments, the first surge protection module further may include a second varistor. An end of the gas discharge tube connected with the positive input end of the power supply may be connected with a first end of the second varistor, and a second end of the second varistor may be connected with the ground end.

[0014] In some embodiments, a first end of the first filtering module may be connected with the positive input end of the power supply, a second end of the first filtering module may be connected with the negative input end of the power supply, a third end of the first filtering module may be connected with a first end of the first residual voltage processing module, and a fourth end of the first filtering module may be connected with a second end of the first residual voltage processing module.

[0015] In some embodiments, the first filtering module may include a third capacitor and a common mode inductor. A first end of the third capacitor may be determined as the first end of the first filtering module and may be connected with a first end of the common mode inductor. A second end of the second capacitor may be determined as the second end of the first filtering module and may be connected with a second end of the common mode inductor. A third end of the common mode inductor may be determined as the third end of the first filtering module. A fourth end of the common mode inductor may be determined as the fourth end of the first filtering module.

[0016] In some embodiments, the first residual voltage processing module may include a first bidirectional transient suppression diode. A first end of the first bidirectional transient suppression diode may be determined as the first end of the first residual voltage processing module, and a second end of the first bidirectional transient suppression diode may be determined as the second end of the first residual voltage processing module.

[0017] In some embodiments, the power surge protection circuit further includes a second filtering module and a second residual voltage processing module. The second filtering module may be configured to reduce an electromagnetic radiation that is generated by the power surge protection circuit when discharging the energy of the differential mode. The second residual voltage processing module may be configured to reduce the residual voltage that is reduced by the first residual voltage processing module.

[0018] In some embodiments, a first end of the second filtering module may be connected with the first end of the first residual voltage processing module. A second end of the second filtering module may be connected with the second end of the first residual voltage processing module. A third end of the second filtering module may be connected with a first end of the second residual voltage processing module. A fourth end of the second filtering module may be connected with a second end of the second residual voltage processing module.

[0019] In some embodiments, the second filtering module may include a fourth capacitor, a fifth capacitor, and a differential mode inductor. A first end of the third capacitor may be determined as the first end of the second filtering module and may be connected with a first end of the differential mode inductor. A second end of the third capacitor may be determined as the second end of the second filtering module. A first end of the fourth capacitor may be determined as the third end of the second filtering module and may be connected with a second end of the differential mode inductor. A second end of the fourth capacitor may be determined as the fourth end of the second filtering module and may be connected with the second end of the third capacitor.

[0020] In some embodiments, the second residual voltage processing module may include a second bidirectional transient suppression diode. A first end of the second bidirectional transient suppression diode may be determined as the first end of the second residual voltage processing module. A second end of the second bidirectional transient suppression diode may be determined as the second end of the second residual voltage processing module.

[0021] In some embodiments, the power surge protection circuit may further include a first fuse and/or a second fuse. The first end of the first filtering module may be connected with the positive

input end of the power supply through the first fuse, and the second end of the first filtering module may be connected with the negative input end of the power supply through the second fuse.

[0022] According to the embodiments of the present disclosure, a device for power protection is provided. The device may include a power supply, and the above power surge protection circuit may be configured to perform the surge protection on the power supply.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The present disclosure will be further described in the form of exemplary embodiments, which will be described in detail by the accompanying drawings. These embodiments are not limiting, in these embodiments, the same number denotes the same structure, wherein:

[0024] FIG. 1 is a schematic diagram illustrating an exemplary power surge protection circuit according to some embodiments of the present disclosure;

[0025] FIG. 2A is a schematic diagram illustrating another exemplary power surge protection circuit according to some embodiments of the present disclosure;

[0026] FIG. 2B is a schematic diagram illustrating another exemplary power surge protection circuit according to some embodiments of the present disclosure;

[0027] FIG. 3A is a schematic diagram illustrating another exemplary power surge protection circuit according to some embodiments of the present disclosure;

[0028] FIG. 3B is a schematic diagram illustrating another exemplary power surge protection circuit according to some embodiments of the present disclosure;

[0029] FIG. 4 is a schematic diagram illustrating another exemplary power surge protection circuit according to some embodiments of the present disclosure;

[0030] FIG. 5 is a schematic diagram illustrating another exemplary power surge protection circuit according to some embodiments of the present disclosure;

[0031] FIG. 6 is a schematic diagram illustrating another exemplary power surge protection circuit according to some embodiments of the present disclosure;

[0032] FIG. 7 is a schematic diagram illustrating another exemplary power surge protection circuit according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

[0033] To more clearly illustrate the technical solutions related to the embodiments of the present disclosure, a brief introduction of the drawings referred to the description of the embodiments is provided below. Obviously, the accompanying drawing in the following description is merely some examples or embodiments of the present disclosure, for those skilled in the art, the present disclosure may further be applied in other similar situations according to the drawings without any creative effort. Unless obviously obtained from the context or the context illustrates otherwise, the same numeral in the drawings refers to the same structure or operation.

[0034] It will be understood that the term “system,” “device,” “unit,” and/or “module” used herein are one method to distinguish different components, elements, parts, sections, or assemblies of different

levels in ascending order. However, if other words may achieve the same purpose, the words may be replaced by other expressions.

[0035] As used in the disclosure and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the descriptions clearly dictate otherwise. Generally speaking, the terms “comprise” and “include” only imply that the clearly determined steps and elements are included, and these steps and elements may not constitute an exclusive list, and the method or device may further include other steps or elements.

[0036] Flowcharts are used throughout the present disclosure to illustrate the operations performed by the system according to embodiments of the present disclosure. It should be understood that the preceding or following operations are not necessarily performed in precise order. Instead, the individual steps may be processed in reverse order or simultaneously. It is also possible to add other operations to these processes or to remove a step or steps of operations from these processes.

[0037] With the development of digital intelligent operation and maintenance business, out of telecommunication, electric power, cultivated land protection, and other business needs, a ball head may be more and more installed in a tower high altitude scene. Most of the iron towers may be built in terrains such as large mountains, suburban areas, uninhabited areas, etc. With global climate warming and increased lightning and rainy weather, an apparatus (such as a monitoring apparatus) arranged on an iron tower may be likely to be damaged by a lightning surge, and if construction and wiring protection is inappropriate, the apparatus may be more likely to be damaged due to the lightning surge. Currently, there are a large count of protection devices used for surge protection of the power supply of the apparatus, resulting in a small layout space on a PCB.

[0038] The embodiments of the present disclosure provide a power surge protection circuit including a first surge protection module, a second surge protection module, and a third surge protection module. The first surge protection module may be configured to cooperate with the second surge protection module to discharge an energy of a first surge (e.g., an energy of a common mode) generated between a positive input end of a power supply and a ground end, and cooperate with the third surge protection module to discharge an energy of a second surge (e.g., the energy of the common mode) generated between a negative input end of the power supply and the ground end. The second surge protection module may be configured to cooperate with the third surge protection module to discharge an energy of a third surge (e.g., an energy of a differential mode) generated between the positive input end of the power supply and the negative input end of the power supply and generate a residual voltage. In some embodiments, the power surge protection circuit may further include a first filtering module and a first residual voltage processing module. The first filtering module may be configured to filter out a noise. The first residual voltage processing module may be configured to reduce a residual voltage.

[0039] The power surge protection circuit described according to some embodiments of the present disclosure may include the second surge protection module and the third surge protection module configured to discharge both the energies of the first surge and the second surge (e.g., the common mode surges) and the energy of the third surge (e.g., the differential mode surge). A differential mode surge protection device (i.e., a second surge protection module 102 and the third surge protection

module 103 shown in FIG. 1) may be used to perform a common mode surge protection, and a common mode surge protection device (i.e., a first surge protection module 101 and the second surge protection module 102 shown in FIG. 1) may be used to perform a differential mode surge protection. Through the above arrangement, the count of protection devices used for surge protection may be reduced, thereby saving a layout space of the PCB of the power surge protection and saves costs; at the same time, a risk of failure of the protection circuit caused by a pressure-sensitive short circuit is reduced.

[0040] FIG. 1 is a schematic diagram illustrating an exemplary power surge protection circuit according to some embodiments of the present disclosure. As shown in FIG. 1, the power surge protection circuit 100 may include a first surge protection module 101, a second surge protection module 102, a third surge protection module 103, a first filtering module 104, and a first residual voltage processing module 105.

[0041] The first surge protection module 101 may be configured to cooperate with the second surge protection module 102 to discharge the energy of a first surge generated between a positive input end VIN_IN of a power supply and a ground end protective earth(PE), and/or cooperate with the third surge protection module 103 to discharge the energy of a second surge generated between a negative input end VIN_GND of the power supply and the ground end PE.

[0042] The second surge protection module 102 may be configured to cooperate with the third surge protection module 103 to discharge the energy of the third surge generated between the positive input end VIN_IN of the power supply and the negative input end VIN_GND of the power supply.

[0043] For ease of description and understanding, the present disclosure embodiments may number (e.g., first end, second end, third end, fourth end) the ports of the modules (e.g., the first surge protection module 101, the second surge protection module 102, the third surge protection module 103, the first filtering module 104, and the first residual voltage processing module 105) of a power surge protection circuit to make connecting relationships between the different modules more clear.

However, the serial numbers of the ports of the modules do not constitute a limitation on the modules, and in other embodiments, the ports of the individual modules may also be renumbered. The serial numbers 1 and 2 at both ends of the first surge protection module 101 shown in the figure may correspond to a first end and a second end of the first surge protection module 101, respectively. The serial numbers 1 and 2 of both ends of the second surge protection module 102 may correspond to a first end and a second end of the second surge protection module 102, respectively. The serial numbers 1, 2, and 3 of three ends of the third surge protection module 103 may correspond to a first end, a second end and a third end of the third surge protection module 103, respectively. The serial numbers 1, 2, 3 and 4 of four ends of the first filtering module 104 may correspond to a first end, a second end, a third end and a fourth end of the first filtering module 104, respectively. The serial numbers 1 and 2 of both ends of the first residual voltage processing module 105 may correspond to a first end and a second end of the first residual voltage processing module 105, respectively.

[0044] In some embodiments, as shown in FIG. 1, the first end of the third surge protection module 103 may be connected with the positive input end VIN_IN of the power supply, and the first end of the

second surge protection module 102, respectively, and the second end of the third surge protection module 103 may be connected with the negative input end VIN_GND of the power supply, the third end of the third surge protection module 103 may be connected with the second end of the second surge protection module 102 and the first end of the second surge protection module 101, respectively, and the second end of the first surge protection module 101 may be connected with the ground end PE.

[0045] The first surge protection module 101 may cooperate with the second surge protection module 102 to conduct a path between the first end of the second surge protection module 102 and the second end of the first surge protection module 101 when a surge (also referred to as a first surge, e.g., a common-mode surge) is generated between the positive input end VIN_IN of the power supply and the ground end PE to discharge the energy of the first surge. Similarly, the first surge protection module 101 may cooperate with the third surge protection module 103 to conduct a path between the second end of the third surge protection module 103 and the second end of the first surge protection module 101 to discharge the energy of a surge (also referred to as a first surge, e.g., a common-mode surge) when the surge is generated between the negative input end VIN_GND of the power supply and the ground end PE.

[0046] The second surge protection module 102 may cooperate with the third surge protection module 103 to conduct a path between the first end of the second surge protection module 102 and the second end of the third surge protection module 103 to discharge the energy of a surge (also referred to as a third surge, e.g., a differential mode surge) when the surge is generated between the positive input end VIN_IN of the power supply and the negative input end VIN_GND of the power supply.

[0047] In some embodiments, the first surge protection module 101 may include one or more varistors (e.g., a first varistor, a second varistor). More descriptions of the first surge protection module 101 may be found in FIG. 2A to FIG. 7 and the descriptions thereof.

[0048] In some embodiments, the second surge protection module 102 may include a first gas discharge tube and a first capacitor connected in parallel, the third surge protection module 103 may include a plurality of second gas discharge tubes and a plurality of second capacitors, and the count of the plurality of second gas discharge tubes may be greater than or equal to two, and a difference between the count of the plurality of second capacitors and the count of the second gas discharge tubes and second capacitors is equal to 1. The count of the plurality of second gas discharge tubes may be greater than the count of the plurality of second capacitors. The plurality of second gas discharge tubes included in the third surge protection module 103 may be connected in series. An end of each of the plurality of second capacitors may be connected with one of nodes of the plurality of second gas discharge tubes connected in series. Each of the nodes of the plurality of second gas discharge tubes may connect two adjacent gas second discharge tubes of the plurality of second gas discharge tubes in the third surge protection module 103. For example, the each of the nodes of the plurality of second gas discharge tubes may be at a second midpoint between two adjacent gas second discharge tubes of the plurality of second gas discharge tubes in the third surge protection module 103. More descriptions of the second surge protection module 102 and the third surge protection module 103 may be found in FIG. 2A and, FIGs. 3A to FIG. 7 and the descriptions thereof.

[0049] In some embodiments, the second surge protection module 102 may include a plurality of first gas discharge tubes connected in series and a plurality of first capacitors. An end of each of each of the first capacitors may be connected with one of nodes of the plurality of first gas discharge tubes. Each of the nodes of the plurality of first gas discharge tubes may connect two adjacent first gas discharge tubes in the second surge protection module 102. The third surge protection module 103 may include a second gas discharge tube and a second capacitor connected in parallel. More descriptions of the second surge protection module 102 and the third surge protection module 103 may be found in FIG. 2B and the descriptions thereof.

[0050] The first filtering module 104 may be configured to filter out noise generated by the power surge protection circuit 100. For example, the power surge protection circuit 100 may generate noises when discharging the energy of the third surge and/or the energies of the first surge and the second surge, and the first filtering module 104 may filter out the noise. The first filtering module 104 may perform low-frequency filtering, high-frequency filtering, and/or common-mode filtering to protect a back-end device (e.g., a diode D1 of the first residual voltage processing module 105) from overvoltage damage.

[0051] The first residual voltage processing module 105 may be configured to reduce a residual voltage. For example, when the second surge protection module 102 cooperates with the third surge protection module 103 to discharge the energy of the third surge, and when the residual voltage reaches the first residual voltage processing module 105, the first residual voltage processing module 105 may absorb a surge spike and a disturbance to reduce a surge voltage and provide a stable and reliable direct current (DC) source for a load circuit.

[0052] As shown in FIG. 1, a first end of the first filtering module 104 may be connected with the positive input end VIN_IN of the power supply, a second end of the first filtering module 104 may be connected with the negative input end VIN_GND of the power supply, a third end of the first filtering module 104 may be connected with a first end of the first residual voltage processing module 105, and a fourth end of the first filtering module 104 may be connected with a second end of the first residual voltage processing module 105. More descriptions of the first filtering module 104 and the first residual voltage processing module 105 may be found elsewhere in the present disclosure, e.g., FIG. 4 and its related description.

[0053] In the power surge protection circuit 100 provided by the embodiments of the present disclosure, the second surge protection module 102 may cooperate with the third surge protection module 103 to discharge the energy of the third surge generated between the positive input end of the power supply and the negative input end of the power supply for a differential mode surge protection. The first surge protection module 101 may cooperate with the second surge protection module 102 to discharge the energy of the first surge generated between the positive input end of the power supply and the ground end for a common mode surge protection, and the first surge protection module 101 may cooperate with the third surge protection module 103 to discharge the energy of the second surge generated between the negative input end of the power supply and the ground end for the common mode surge protection. The power surge protection circuit 100 provided by the embodiments of the

present disclosure embodiment may use a module (e.g., the second surge protection module 102, the third surge protection module 103) for differential surge protection when performing the common mode surge protection, thereby saving the count of devices of the common mode surge protection and the layout space of the PCB, and causing a discharge path of the common mode surge protection to be shorter.

[0054] FIG. 2A is a schematic diagram illustrating another exemplary power surge protection circuit 200 according to some embodiments of the present disclosure. The power surge protection circuit 200 may include the first surge protection module 101, the second surge protection module 102, and the third surge protection module 103. The third surge protection module 103 may include a plurality of second gas discharge tubes and the count of the second gas discharge tubes may equal to 2.

[0055] As shown in FIG. 2A, the first surge protection module 101 may include a first varistor RV1, and the second surge protection module 102 may include a first gas discharge tube GDT1 and a first capacitor C1 connected in parallel.

[0056] A first end of the first varistor RV1 (e.g., end a1 in FIG. 2A) may be determined as a first end of the first surge protection module 101, and a second end of the first varistor RV1 (e.g., end a2 in FIG. 2A) may be determined as a second end of the second surge protection module 101. Another end of the first gas discharge tube GDT1 connected with the positive input end VIN_IN of the power supply (i.e., an end of the first gas discharge tube GDT1 of the second surge protection module 102 that is not connected with the positive input end VIN_IN of the power supply) may be connected with a first end of the first varistor RV1, and the second end of the first varistor RV1 may be connected with the ground end PE.

[0057] A varistor is a component having a function of transient voltage suppression. When a voltage added to the varistor exceeds a certain value (e.g., an operating voltage), a resistance of the varistor may drop rapidly to conduct a large current to protect the back-end circuit. When a voltage added to the varistor is lower than the operating voltage of the varistor, the resistance of the varistor is extremely high, which is equivalent to an open circuit and does not affect an operating state of the back-end circuit. The main features of the varistor are that a range of the operating voltage is wide, a pulse response velocity is fast, a capability of resisting an impulse current is strong, a leakage current is small, a temperature coefficient of resistance is small, and a volume is small. In some embodiments, the varistor may be a silicon carbide varistor, a zinc oxide varistor, or other varistors. In some embodiments, a model of the varistor may be selected according to a power line lap demand and a power port AC500V insulation withstand voltage demand, for example, the varistor (e.g., the varistor RV1, a varistor RV2) and a combined action voltage of each gas discharge tube GDT1 should be higher than DC707V, for example the varistor may be selected as 20D821, and a breakdown voltage of each of the gas discharge tubes GDT1 may be selected between 140V~250V.

[0058] In some embodiments, the first capacitor C1 may be a Y capacitor configured to suppress a common mode interference between the positive input end VIN_IN of the power supply or the negative input end VIN_GND of the power supply and the ground end PE. For example, the first capacitor C1 may be a Y1 capacitor, a Y2 capacitor, etc.

[0059] The first end of the first gas discharge tube GDT1 and the first capacitor C1 connected in parallel (e.g., end b1 in FIG. 2A) may be determined as the first end of the second surge protection module 102, and the first gas discharge tube GDT1 and a second end of the first capacitor C1 connected in parallel (e.g., end b2 in FIG. 2A) may be determined as the second end of the second surge protection module 102.

[0060] A gas discharge tube (GDT) is a discharge gap sealed in a ceramic cavity filled with an inert gas to stabilize the discharge voltage of the discharge tube. The main features of the GDT are large through-current energy, which may reach tens to hundreds of kaas, extremely high insulation resistance, no leakage current, no ageing failure, no polarity bidirectional protection, and extremely small static capacitance. In some embodiments, the GDT1 may be a helium-neon laser tube (HeNe laser tube), an argon ion laser tube (Ar ion laser tube), a silicon nitride discharge tube (Si3N4 discharge tube), or a diode gas discharge tube (DBD gas discharge tube), and the like. In some embodiments, a model of the GDT1 needs to meet a preset surge test (e.g., a 1.2/50us combined differential mode 20KV/common mode 20KV surge test, and/or an 8/20us combined differential mode 10KA/common mode 10KA surge test) and/or be combined with other devices (e.g., other GDT1s and/or varistors) at a voltage higher than a preset voltage (e.g., higher than DC707V).

[0061] In conjunction with the above, the third surge protection module 103 may include the plurality of second gas discharge tubes and the plurality of second capacitors. In some embodiments, the plurality of second gas discharge tubes GDT1 may be connected in series between the second end of the second surge protection module 102 and the negative input end VIN_GND of the power supply. An end of a second gas discharge tube GDT1 connected with the second end of the second surge protection module 102 may be determined as the third end of the third surge protection module 103, and an end of the second gas discharge tubes GDT1 connected with the negative input end VIN_GND of the power supply may be determined as the second end of the third surge protection module 103. The first end of one of the plurality of second capacitors C1 may be determined as the first end of the third surge protection module 103, and the second end of each of the plurality of second capacitors C1 may be connected with one node of two adjacent second gas discharge tubes GDT1.

[0062] For example, as shown in FIG. 2A, the third surge protection module 103 may include two second gas discharge tubes GDT1 connected in series and a second capacitor C1. The two second gas discharge tubes GDT1 may be connected in series between the second end of the second surge protection module 102 and the negative input end VIN_GND of the power supply, the gas discharge tubes GDT1 may be connected with the second end of the third surge protection module 102 as a third end of the third surge protection module. An end c3 of a second gas discharge tube GDT1 connected with the second end of the second surge protection module 102 may be determined as the third end of the third surge protection module 103, and an end c2 of a second gas discharge tube GDT1 connected with the negative input end VIN_GND of the power supply may be determined as the second end of the third surge protection module 103. A second end c4 of the second capacitor C1 may be connected with a connection node of the two second gas discharge tubes GDT1, and a first end c1 of the second capacitor C1 may be determined as a first end of the third surge protection module 103.

[0063] In the power surge protection circuit, a plurality of gas discharge tubes GDT1 (e.g., the plurality of second gas discharge tubes of the third surge protection module and the first gas discharge tube of the second surge protection module in FIG. 2A, or a plurality of first gas discharge tubes of the second surge protection module 102 and the second gas discharge tube of the third surge protection module in FIG. 2B) may be connected in series. For example, each of the plurality of second gas discharge tubes GDT1 may be arranged on a PCB, and a plurality of PCBs may be connected in series to realize the series connection of the plurality of second gas discharge tubes GDT1. In some embodiments, the plurality of gas discharge tubes GDT1 (e.g., the plurality of second gas discharge tubes of the third surge protection module and the first gas discharge tube of the second surge protection module) may form a cascade gas discharge, i.e., the plurality of gas discharge tubes GDT1 may be arranged on the same PCB to form the cascade gas discharge, and the cascade gas discharge as a whole may be used in a power surge protection circuit, and the overall sizes of the power surge protection circuit may be reduced in this manner such that the overall sizes of the power surge protection circuit may be reduced.

[0064] In connection with FIG. 2A, when a first surge is generated between the positive input end VIN_IN of the power supply and the ground end PE, the energy of the first surge may flow through the first gas discharge tube GDT1 of the second surge protection module 102) connected with the positive input end VIN_IN of the power supply and the first varistor RV1, flow through the first capacitor C1 of the second surge protection module 102 and the first varistor RV1, and discharge the energy of the first surge between the positive input end VIN_IN of the power supply and the ground end PE. When a second surge is generated between the negative input end VIN_GND of the power supply and the ground end PE, the energy of the second surge may flow through the two second gas discharge tubes GDT1 of the third surge protection module 103 connected in series with the negative input end VIN_GND of the power supply in turn and the first varistor RV1, and discharge the energy of the second surge between the negative input end VIN_GND of the power supply and the ground end PE.

[0065] When a third surge is generated between the positive input end VIN_IN of the power supply and the negative input end VIN_GND of the power supply, the first capacitor C1 of the second surge protection module 102 and the second capacitor C1 of the third surge protection module 103 may conduct to each other, and a breakdown of conduction between the first gas discharge tubes GDT1 of the second surge protection module 102 and the two second gas discharge tubes GDT1 of the third surge protection module 103 may be accelerated, such that the energy of the third surge between the positive input end VIN_IN of the power supply and the negative input end VIN_GND of the power supply may be discharged.

[0066] In the present disclosure embodiment, one or more devices for differential mode protection (e.g., the first gas discharge tube GDT1 and/or the second gas discharge tube GDT1 of the second surge protection module and/or the third surge protection module) may be used for common mode protection, which on the one hand saves the cost of the device and the count of devices, and on the other hand solves the risk of short circuit failure of the varistor. In addition, since an action voltage of the varistor is relatively high, the action voltage in the present disclosure embodiment is high when the

common mode protection is performed, which may satisfy a power line overlap requirement and may also satisfy a AC500V insulation withstand voltage requirement.

[0067] In some embodiments, an breakdown order of conduction of each of the plurality of gas discharge tubes GDT1 (e.g., the first gas discharge tubes GDT1 of the second surge protection module 102 and the two second gas discharge tubes GDT1 of the third surge protection module 103 in FIG. 2A, or the two first gas discharge tubes GDT1 of the second surge protection module 102 and the second gas discharge tube GDT1 of the third surge protection module 103 in FIG. 2B below) is generally from bottom to top (as in FIG. 2A or FIG. 2B, along a direction from the gas discharge tubes directly connected with the negative input end VIN_GND of the power supply to the gas discharge tubes directly connected with the positive input end VIN_IN of the power supply). This approach may reduce the residual voltage as a whole, which is smaller than a conventional approach of gas discharge tubes connected in series with varistors, after the differential mode protection is performed, thereby enabling a back stage circuitry to withstand the level of residual voltage.

[0068] In addition, relative to differential mode surge protection in the form of a separate varistor, the differential mode surge protection structure described above may be less prone to short-circuiting and causing fires, and when supplied at low voltages, the differential mode surge protection may be many times the renewal maintenance voltage of a single gas discharge tube GDT1, and does not cause a renewal problem when the surge occurs.

[0069] It should be noted that FIG. 2A is merely an exemplary power surge protection circuit structure, and in other embodiments, any modification based on the same inventive idea may be made to form a power surge protection circuit structure having similar functions and/or effects, such as, the structure of the power surge protection circuit shown in FIG. 2B.

[0070] FIG. 2B is a schematic diagram illustrating another exemplary power surge protection circuit 200 according to some embodiments of the present disclosure. As shown in FIG. 2B, the second surge protection module 102 may include a plurality of first gas discharge tubes connected in series and one or more first capacitors connected in series, and a third surge protection module 103 may include a second gas discharge tube and a second capacitor connected in parallel. A count of the plurality of first gas discharge tubes may be greater than or equal to two, a difference between a count of the plurality of first capacitors and the count of the plurality of first gas discharge tubes may be equal to 1.

[0071] As shown in FIG. 2B, the first surge protection module 101 may include a varistor RV1, the second surge protection module 102 may include two first gas discharge tubes GDT1 and a first capacitor C1, and the third surge protection module 103 may include a second gas discharge tube GDT1 and a second capacitor C1 connected in parallel.

[0072] An end of the second gas discharge tube GDT1 connected with the second capacitor C1 (e.g., end c3 as shown in FIG. 2B) of the third surge protection module 103 may be determined as a third end of the third surge protection module 103, and a first end of the second gas discharge tube GDT1 may be connected with a second end of the second capacitor C1. A second end of the second gas discharge tube GDT1 (as c2 end in FIG. 2B) may be determined as a second end of the third surge

protection module 103. A first end of the second capacitor C1 (e.g., end c1 as shown in FIG. 2B) may be determined as the first end of the third surge protection module 103. The second end of the second gas discharge tube GDT1 may be connected with the negative input end VIN_GND of the power supply.

[0073] The second surge protection module 102 may include a plurality of first gas discharge tubes connected in series and one or more first capacitors. In some embodiments, the plurality of first gas discharge tubes GDT1 may be connected in series between the third end of the third surge protection module 103 and the positive input end VIN_IN of the power supply. An end of the first gas discharge tube GDT1 connected with the third end of the third surge protection module 103 may be determined as the second end of the second surge protection module 102, and an end of one of the plurality of the first gas discharge tube GDT1 connected with the positive input end VIN_IN of the power supply may be determined as the first end of the second surge protection module 102.

[0074] As an example, the second surge protection module 102 may include two first gas discharge tubes GDT1 connected in series and a first capacitor C1 as shown in FIG. 2B. The two gas discharge tubes GDT1 may be connected in series between a third end of the third surge protection module 103 and a positive input end VIN_IN of the power supply. An end of the one of the two first gas discharge tubes GDT1 connected with the third end of the third surge protection module 103 (e.g., end b2 in FIG. 2B) may be determined as the second end of the second surge protection module 102, and an end of one of the two first gas discharge tubes GDT1 connected with the positive input end VIN_IN of the power supply (e.g., end b1 in FIG. 2B) may be determined as the first end of the second surge protection module 102. An end of the first capacitor C1 may be connected with the connection node z of the two first gas discharge tubes GDT1, and another end of the first capacitor C1 may be connected with the positive input end VIN_IN of the power supply.

[0075] In connection with FIG. 2B, when a second surge is generated between the negative input end VIN_GND of the power supply and the ground end PE, the energy of the second surge may flow through the second gas discharge tube GDT1 of the third surge protection module 103 connected with the negative input end VIN_GND of the power supply and the first varistor RV1, to discharge the energy of the second surge between the negative input end VIN_GND of the power supply and the ground end PE. When the first surge is generated between the positive input end VIN_IN of the power supply and the ground end PE, the energy of the first surge may flow through the two first gas discharge tubes GDT1 of the second surge protection module 102 and the first varistor RV1 connected in series with the positive input end VIN_IN of the power supply in turn, and discharge the energy of the first surge between the positive input end VIN_IN of the power supply and the ground end PE.

[0076] When a third surge is generated between the positive input end VIN_IN of the power supply and the negative input end VIN_GND of the power supply, the first capacitor C1 of the second surge protection module 102 and the second capacitor C1 of the third surge protection module 103 may conduct, and a breakdown of conduction of the two first gas discharge tubes GDT1 of the second surge protection module 102 and the second gas discharge tube GDT1 of the third surge protection module 103 may be accelerated, such that the energy of the third surge may be discharged.

[0077] In some embodiments, the first surge protection module 101 may include two varistors. Another end of the second gas discharge tube connected with the negative input end VIN_GND of the power supply, may be connected with the first end of the second varistor (as shown in FIG. 3A), or another end of the gas discharge tube connected with the positive input end of the power supply may be connected with the first end of the second varistor (as shown in FIG. 3B), and the second end of the second varistor may be connected with the ground end PE.

[0078] FIG. 3A is a schematic diagram illustrating another exemplary power surge protection circuit 300 according to some embodiments of the present disclosure. As shown in FIG. 3A, the power surge protection circuit 300 may include the first surge protection module 101, the second surge protection module 102, and the third surge protection module 103. The first surge protection module 101 may include two varistors (i.e., the first varistor RV1 and the second varistor RV2). The third surge protection module 103 may include a plurality of second gas discharge tubes and a plurality of second capacitors. The count of the second gas discharge tubes may equal to 4 and the plurality of second capacitors may be equal to 3.

[0079] As shown in FIG. 3A, in some embodiments, the first surge protection module 101 may further include a second varistor RV2, the second surge protection module 102 may include a first gas discharge tube GDT1 and a first capacitor C1 connected in parallel, and the third surge protection module 103 may include four second gas discharge tubes connected in series and three second capacitors.

[0080] One end of one of the four second gas discharge tubes GDT1 connected with the negative input end VIN_GND of the power supply (e.g., end c5 in FIG. 3A) may be connected with a first end (e.g., end a3 in FIG. 3A) of the second varistor RV2, and the second end of the second varistor RV2 (end a4 in FIG. 3A) may be connected with the ground end PE.

[0081] Similar to FIG. 2A, a first end of the first gas discharge tube GDT1 and the first capacitor C1 connected in parallel (e.g., end b1 in FIG. 3A) may be determined as a first end of the second surge protection module 102, and a second end of the first gas discharge tube GDT1 and the first capacitor C1 connected in parallel (e.g., end b2 in FIG. 3A) may be determined as the second end of the second surge protection module 102.

[0082] When a count of the plurality of gas discharge tubes (the total count of the first gas discharge tube and the second gas discharge tubes) may be greater than or equal to four (i.e., the third surge protection module 103 may include four second gas discharge tubes GDT1), as shown in FIG. 3A, the third surge protection module 103 may include four second gas discharge tubes GDT1 connected in series and three first second capacitors C1. The four second gas discharge tubes GDT1 may be connected in series between the second end of the second surge protection module 102 and the negative input end VIN_GND of the power supply, an end c3 of the second gas discharge tube GDT1 connected with the second end of the second surge protection module 102 may be determined as the third end of the third surge protection module 103, and an end c2 of the second gas discharge tube GDT1 connected with the negative input end VIN_GND of the power supply may be determined as the second end of the third surge protection module 103. The second end of each of the three first

capacitors C1 (e.g., end c4 in FIG. 3A) may be connected with one of the connection nodes (e.g., points z1, z2, and z3 in the figure) of two adjacent second gas discharge tubes GDT1, and a first end c1 of one of the three first capacitors C1 may be determined as the first end of the third surge protection module 103.

[0083] In connection with FIG. 3A, when a third surge is generated between the positive input end VIN_IN of the power supply and the negative input end VIN_GND of the power supply, the first capacitor C1 of the second surge protection module 102 and the three second capacitors C1 of the third surge protection module 103 may conduct, a breakdown of conduction of the first gas discharge tube GDT1 of the second surge protection module 102 and the four second gas discharge tubes GDT1 of the third surge protection module 103 may be accelerated, such that the energy of the third surge may be discharged.

[0084] In some embodiments, an breakdown order of conduction of the plurality of gas discharge tubes GDT1 (e.g., the first gas discharge tube GDT1 of the second surge protection module 102 and the four second gas discharge tubes GDT1 of the third surge protection module 103 in FIG. 2A) is generally from bottom to top (as in FIG. 3A, along a direction from the gas discharge tube directly connected with the negative input end VIN_GND of the power supply to the gas discharge tube directly connected with the positive input end VIN_IN of the power supply). This approach may reduce the residual voltage as a whole, so that a rear-stage circuit may bear the residual voltage level, thereby improving a reliability of the power supply surge protection of the device.

[0085] When a first surge is generated between the positive input end VIN_IN of the power supply and the ground end PE, the energy of the first surge may flow through the topmost gas discharge tube GDT1 (i.e., the first gas discharge tube GDT1 of the second surge protection module 102) and the first varistor RV1, thereby discharging the energy of the first surge between the positive input end VIN_IN of the power supply and the ground end PE. When a second surge is generated between the negative input end VIN_GND of the power supply and the ground end PE, the energy of the second surge may flow through the lowest gas discharge tube GDT1 (i.e., the second gas discharge tube GDT1 of the third surge protection module 103 connected with the negative input end VIN_GND of the power supply) and the second varistor RV2, thereby discharging the energy of the second between the negative input end VIN_GND of the power supply and the ground end PE. Based on the power surge protection circuit structure shown in FIG. 3A, the first surge protection circuit may be designed as a symmetrical structure, so that regardless of whether the first surge is generated between the positive input end VIN_IN of the power supply and the ground end PE, or the second surge is generated between the negative input end VIN_GND of the power supply and the ground end PE, the energies of the first surge and the second surge may be efficiently discharged either from the negative input end VIN_IN of the power supply to the ground end PE or from the negative input end VIN_GND of the power supply to the ground end PE, the two discharge path may be basically equal, thereby improving the stability of surge protection.

[0086] It should be noted that the exemplary structure of circuit illustrating in FIG. 3A is that the second surge protection module 102 may include a first gas discharge tube and a first capacitor

connected in parallel, and the third surge protection module 103 may include a plurality of second gas discharge tubes and a plurality of second capacitors connected in series. In other alternative embodiments, the power surge protection circuit structure may also be configured such that the second surge protection module 102 may include first second gas discharge tubes connected in series and a plurality of first capacitors, and the third surge protection module 103 may include may include a second gas discharge tube and a second capacitor connected in parallel.

[0087] In the structure of circuit shown in FIG. 3A, another end of the gas discharge tube GDT1 connected with the positive input end VIN_IN of the power supply may be connected with the first end of the first varistor RV1, and another end of the gas discharge tube GDT1 connected with the negative input end VIN_GND of the power supply may be connected with a first end of the second varistor RV2, and in other embodiments, an end of the as discharge tube GDT1 may be connected with an end of the first varistor RV1 or the second varistor RV2 through other connection.

[0088] FIG. 3B is a schematic diagram illustrating another exemplary power surge protection circuit 300 according to some embodiments of the present disclosure. As shown in FIG. 3B, the power surge protection circuit 300 may include the first surge protection module 101, the second surge protection module 102, and the third surge protection module 103. The first surge protection module 101 may include two varistors (i.e., the first varistor RV1 and the second varistor RV2). The third surge projection module 103 may include a plurality of second gas discharge tubes and a plurality of second capacitors. The count of the second gas discharge tubes may equal to 2 and the plurality of second capacitors may be equal to 1 tubes m.

[0089] As shown in FIG. 3B, one end of the second gas discharge tube connected with the negative input end VIN_GND of the power supply (i.e., an end of the second gas discharge tube directly connected with the negative input end VIN_GND of the power supply of the third surge protection module 103 that is not connected with the negative input end VIN_GND, e.g., an end c5 of FIG. 3B) may be connected with a first end a1 of the first varistor RV1, and a second end a2 of the first varistor RV1 may be connected with the ground end PE. One end of the first gas discharge tube connected with the positive input end VIN_IN of the power supply (i.e., the end of the first gas discharge tube of the second surge protection module 102 that is not connected with VIN_IN, such as a b2 end in FIG. 3B) may be connected with a first end a3 of the second varistor RV2, and a second end a4 of the second varistor RV2 may be connected with the ground end PE.

[0090] As an example, when a count of the plurality of first gas discharge tubes is equal to two, the second surge protection module 102 may include a first gas discharge tube and a first capacitor connected in parallel, and the third surge protection module 103 may include two second gas discharge tubes and a second capacitor connected in series.

[0091] In the second surge protection module 102, the first end of the first gas discharge tube GDT1 and the first capacitor C1 connected in parallel may be determined as the first end of the second surge protection module 102, and the second end of the first gas discharge tube GDT1 and the first capacitor C1 connected in parallel may be determined as the second end of the second surge protection module 102.

[0092] In the third surge protection module 103, the two second gas discharge tubes GDT1 may be connected in series between the second end of the second surge protection module 102 and the negative input end VIN_GND of the power supply, and an end of one of the second gas discharge tubes GDT1 connected with the second end of the second surge protection module 102 (e.g., the c3 end in FIG. 3B) may be determined as the third end of the third surge protection module 103, and an end of the second gas discharge tube GDT1 (as shown at end c2 in FIG. 3B) may be determined as the second end of the third surge protection module 103. The second end of the second capacitor C1 (e.g., end c4 in FIG. 3B) may be connected with the connection node (e.g., point z in FIG. 3B) of the two second gas discharge tubes GDT1, and a first end of the second capacitor C1 (e.g., end c1 in FIG. 3B) may be determined as the first end of the third surge protection module 103.

[0093] When a third surge is generated between the positive input end VIN_IN of the power supply and the positive input end VIN_GND of the power supply, the first capacitor of the second surge protection module 102 and the second capacitor of the third surge protection module 103 may conduct, a breakdown of conduction of the first gas discharge tube of the second surge protection module 102 and the two second gas discharge tubes of the third surge protection module 103 may be accelerated, such that the energy of the third surge may be discharged

[0094] When a first surge is generated between the positive input end VIN_IN of the power supply and the ground end PE, the energy of the first surge may flow through the first gas discharge tube of the second surge protection module 102 connected with the positive input end VIN_IN of the power supply and the second varistor RV2, thereby discharging the energy of the first surge between the positive input end VIN_IN of the power supply and the ground end PE. When a second surge is generated between the negative input end VIN_GND of the power supply and the ground end PE, the energy of the second surge may flow through the second gas discharge tube in the third surge protection module 103 that is directly connected with the negative input end VIN_GND of the power supply and the first varistor RV1, thereby discharge the energy of the second surge between the negative input end VIN_IN of the power supply and the ground end PE. Based on the power surge projection circuit shown in FIG. 3A, the first surge protection circuit 101 may be designed as a symmetrical structure, so that regardless of whether the first surge is generated between the positive input end VIN_IN of the power supply and the ground end PE, or the second surge is generated between the negative input end VIN_GND of the power supply and the ground end PE, the energies of the first surge and the second surge may be efficiently discharged either from the negative input end VIN_IN of the power supply to the ground end PE or from the negative input end VIN_GND of the power supply to the ground end PE, and the two discharge paths may be basically equal, thereby improving the stability of surge protection.

[0095] In alternative embodiments, the first varistor RV1 and/or the second varistor RV2 may also be replaced with a bidirectional transient suppression diode or a semiconductor discharge tube.

[0096] FIG. 4 is a schematic diagram illustrating another exemplary power surge protection circuit 400 according to some embodiments of the present disclosure. As shown in FIG. 4, the power surge protection circuit 400 may include the first surge protection module 101, the second surge protection

module 102, and the third surge protection module 103. The first surge protection module 101 may include two varistors (i.e., the first varistor RV1 and the second varistor RV2). The third surge projection module 103 may include a plurality of second gas discharge tubes and a plurality of second capacitors. The count of the second gas discharge tubes may equal to 4 and the plurality of second capacitors may be equal to 3.

[0097] As shown in FIG. 4, the first filtering module 104 may include a third capacitor C2 and a common mode inductor FIL1. A first end d1 of the third capacitor C2 may be determined as a first end of the first filtering module 104 and may be connected with a first end e1 of the common mode inductor FIL1, a second end d2 of the third capacitor C2 may be determined as a second end of the first filtering module 104 and may be connected with a second end e2 of the common mode inductor FIL1, a third end e3 of the common mode inductor FIL1 may be determined as a third end of the first filtering module 104, and a fourth end e4 end of the common mode inductor FIL1 may be determined as a fourth end of the first filtering module 104.

[0098] In some embodiments, the third capacitor C2 may be an X capacitor configured to perform a differential mode filtering. For example, the third capacitor C2 may be an X2 capacitor. The common mode inductor FIL1 may be a filter inductor capable of suppressing a common mode interference. The common mode inductor FIL1 may filter out a common mode noise, and in addition may play a decoupling role, and may limit a lightning strike overcurrent. The third capacitor C2 and the common mode inductor FIL1 may cooperate to perform a low frequency filtering, a high frequency filtering, a differential mode filtering and/or a common mode filtering to protect a back-end device from overvoltage damage.

[0099] As shown in FIG. 4, the first residual voltage processing module 105 may include a first diode D1 (e.g., a bidirectional transient suppression diode). A first end f1 of the first diode D1 may be determined as a first end of the first residual voltage processing module 105, and a second end f2 of the first bidirectional transient suppression diode D1 may be determined as a second end of the first residual voltage processing module 105.

[0100] The first diode D1 may reduce the residual voltage. For example, when the second surge protection module 102 cooperates with the third surge protection module 103 to discharge the energy of the third surge and the residual voltage reaches the first diode D1, the first diode D1 may absorb the surge spike and the disturbance to reduce a surge voltage and provide a stable and reliable direct current source for the load circuit. In other embodiments, the first diode D1 may reduce the residual voltage through other manners, for example, the varistor or the semiconductor discharge tube may further be configured to reduce the residual voltage.

[0101] It should be understood that the structures of the first filtering module 104 and the first residual voltage processing module 105 may be the same when the first surge protection module 101 include a varistor or a count of the plurality of gas discharge tubes is equal to other values, and at this time, the power surge protection circuit may provide a similar protective effect.

[0102] FIG. 5 is a schematic diagram illustrating another exemplary power surge protection circuit 500 according to some embodiments of the present disclosure. As shown in FIG. 5, the power surge

protection circuit 500 may include the first surge protection module 101, the second surge protection module 102, the third surge protection module 103, the first filtering module 104, and the first residual voltage processing module 105. The first surge protection module 101 may include two varistors (i.e., the first varistor RV1 and the second varistor RV2). The third surge projection module 103 may include a plurality of second gas discharge tubes and a plurality of second capacitors. The count of the second gas discharge tubes may equal to 4 and the plurality of second capacitors may be equal to 3.

[0103] Different from the power surge protection circuit 500 as shown in FIG. 4, as shown in FIG. 5, the power surge protection circuit 500 may further include a second filtering module 106 and a second residual voltage processing module 107. The second filtering module 106 may be configured to reduce an electromagnetic radiation. The power surge protection circuit 500 may generate electromagnetic radiation when discharging an energy of a differential surge or an energy of the common-mode surges (e.g., the first surge and the second surge), and the second filtering module 106 may reduce the electromagnetic radiation. The second residual voltage processing module 107 may be configured to reduce the residual voltage that is reduced by the first residual voltage processing module 105. For example, when the residual voltage processed by the first residual voltage processing module 105 (e.g., the first diode D1) reaches the second residual voltage processing module 107, the second residual voltage processing module 107 may further absorb the surge spike and the disturbance, reduce the surge voltage again that is reduced by the first residual voltage processing module, and provide the load circuit with a stable and reliable direct current source.

[0104] A first end of the second filtering module 106 may be connected with a first end of the first residual voltage processing module 105, a second end of the second filtering module 106 may be connected with a second end of the first residual voltage processing module 105, a third end of the second filtering module 106 may be connected with a first end of the second residual voltage processing module 107, and a fourth end of the second filtering module 106 may be connected with a second end of the second residual voltage processing module 107. More descriptions of the second filtering module 106 and the second residual voltage processing module 107 may be found in FIG. 6 and its related description.

[0105] FIG. 6 is a schematic diagram illustrating another exemplary power surge protection circuit 600 according to some embodiments of the present disclosure. As shown in FIG. 6, the power surge protection circuit 600 may include the first surge protection module 101, the second surge protection module 102, the third surge protection module 103, the first filtering module 104, the first residual voltage processing module 105, the second filtering module 106, and the second residual voltage processing module 107. The first surge protection module 101 may include two varistors (i.e., the first varistor RV1 and the second varistor RV2). The third surge projection module 103 may include a plurality of second gas discharge tubes and a plurality of second capacitors. The count of the second gas discharge tubes may equal to 4 and the plurality of second capacitors may be equal to 3.

[0106] As shown in FIG. 6, the second filtering module 106 may include a third capacitor C3, a fourth capacitor C4, and a differential mode inductor L1. A first end g1 of the third capacitor C3 may be

determined as a first end of the second filtering module 106 and may be connected with a first end h1 of the differential mode inductor L1. A second end g2 of the third capacitor C3 may be determined as a second end of the second filtering module 106. A first end g3 of the fourth capacitor C4 may be determined as a second third end of the filtering module 106 and may be connected with the second end h2 of the differential mode inductor L1. A second end g4 of the fourth capacitor C4 may be determined as the fourth end of the second filtering module and may be connected with the second end g2 of the third capacitor C3.

[0107] In some embodiments, the third capacitor C3 and the fourth capacitor C4 may be porcelain chip capacitors. The porcelain chip capacitors and the differential mode inductor L1 may form a π -filter circuit that may optimize electro-magnetic compatibility (EMC) radiation and conduction.

[0108] The second residual voltage processing module 107 may include a second bidirectional transient suppression diode D2. A first end k1 of the second bidirectional transient suppression diode D2 may be determined as a first end of the second residual voltage processing module 107, and a second end k2 of the second bidirectional transient suppression diode D2 may be determined as a second end of the second residual voltage processing module 107. In other embodiments, the residual voltage may be reduced through other manners, for example, the varistors or the semiconductor discharge tubes may also be configured to reduce the residual voltage.

[0109] It should be understood that, when the first surge protection module 101 may include a varistor or the count of the second gas discharge tubes is of some other value, the structures of second filtering module 106 and the second residual voltage processing module 107 may be the same, at which time the power surge protection circuit may provide a similar protective effect.

[0110] The power surge protection circuits provided by the embodiments of the present disclosure, may at least meet a requirement of high-level surge design including differential mode 10KA/common mode 10KA, differential mode 20KV/common mode 20KV, and a size of devices of the power surge protection circuit may be relatively small and maybe friendly to a PCB layout.

[0111] FIG. 7 is a schematic diagram illustrating another exemplary power surge protection circuit 700 according to some embodiments of the present disclosure.

[0112] As shown in FIG. 7, the power surge protection circuit 700 may include the first surge protection module 101, the second surge protection module 102, the third surge protection module 103, the first filtering module 104, the first residual voltage processing module 105, the second filtering module 106, and the second residual voltage processing module 107. The first surge protection module 101 may include two varistors (i.e., the first varistor RV1 and the second varistor RV2). The third surge projection module 103 may include a plurality of second gas discharge tubes and a plurality of second capacitors. The count of the second gas discharge tubes may equal to 4 and the plurality of second capacitors may be equal to 3. As shown in FIG. 7, the power surge protection circuit 700 may further include a first fuse F1 and/or a second fuse F2. In some embodiments, the power surge protection circuit 700 may include a fuse such as the first fuse F1 or the second fuse F2. Taking the power surge protection circuit 700 including the first fuse F1 and the second fuse F2 as an example, a first end of the first filtering module 104 may be connected with the positive input end VIN_IN of the

power supply through the first fuse F1, and a second end of the first filtering module 104 may be connected with a negative input end VIN_GND of the power supply, through the second fuse F2. When the power surge protection circuit 700 fails, for example, when a rear stage bidirectional transient suppression diode is short-circuited and fails, the fuses (the first fuse F1 and/or the second fuse F2) may be blown to cut off the entire circuit, thereby providing circuit protection.

[0113] In some embodiments, one or more components of the power surge protection circuit satisfy a preset condition. For example, to meet a design requirement including a surge test of 1.2/50us (voltage wave) combined wave differential mode 20KV/common mode 20KV, a surge test of 8/20us (current wave) combined wave differential mode 10KA/common mode 10KA, the configuration of the first and/or second gas discharge tube GDT1 of the second surge protection module 102 and/or the third surge protection module 103, as well as the first voltage sensitive resistor RV1 and/or the second voltage sensitive resistor RV2, may be such that at least a current capacity of 8/20us lightning test waveform 10KA may be satisfied. Peak pulse powers of the bidirectional transient suppression diodes D1 and D2 may be at least 5000W. PCB alignments of the first surge protection module 101, the second surge protection module 102 and the third surge protection module 103 may include a 10Z line width of 200 mils (or a 20Z line width of 100 mils) or more. As another example, to satisfy a power line lap demand and a power port AC500V insulation withstand voltage demand, the combined action voltage of the first varistor RV1 and/or the second varistor RV2 in the first surge protection module 101, for the first and/or second gas discharge tubes GDT1 of the second surge protection module 102 and/or the third surge protection module 103, should be higher than DC707V, for example, the varistor may be determined as 20D821, and a breakdown voltage of each of the gas discharge tubes GDT1 may be determined between 140V and 250V.

[0114] It should be noted that the above parameters are merely provided for the purpose of an example, and the present disclosure does not make any limitation on this. The model and parameters of each device of the power surge protection circuit (e.g., the gas discharge tube, the capacitor, the varistor, the bidirectional transient suppression diode, etc.) may be reasonably selected according to the requirements of the actual application.

[0115] The present disclosure further provides a device for power protection, the device may include a power supply and the power surge protection circuit described in any one of the embodiments of the present disclosure. The power surge protection circuit may be configured to discharge the energy of the first surge (e.g., the surge of the common mode surge) and/or the energy of the second surge (e.g., the surge of the differential mode surge) to perform the surge protection on the power supply.

[0116] Having thus described the basic concepts, it may be rather apparent to those skilled in the art after reading this detailed disclosure that the foregoing detailed disclosure is intended to be presented by way of example only and is not limiting. Various alterations, improvements, and modifications may occur and are intended for those skilled in the art, though not expressly stated herein. These alterations, improvements, and modifications are intended to be suggested by the present disclosure, and are within the spirit and scope of the exemplary embodiments of the present disclosure.

[0117] Moreover, certain terminology has been used to describe embodiments of the present

disclosure. For example, the terms “one embodiment,” “an embodiment,” and/or “some embodiments” mean that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Therefore, it is emphasized and should be appreciated that two or more references to “an embodiment” or “one embodiment” or “an alternative embodiment” in various portions of this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined as suitable in one or more embodiments of the present disclosure.

[0118] Furthermore, the recited order of processing elements or sequences, or the use of numbers, letters, or other designations thereof, are not intended to limit the claimed processes and methods to any order except as may be specified in the claims. Although the above disclosure discusses through various examples what is currently considered to be a variety of useful embodiments of the disclosure, it is to be understood that such detail is solely for that purpose, and that the appended claims are not limited to the disclosed embodiments, but, on the contrary, are intended to cover modifications and equivalent arrangements that are within the spirit and scope of the disclosed embodiments. For example, although the implementation of various components described above may be embodied in a hardware device, it may also be implemented as a software-only solution, e.g., an installation on an existing server or mobile device.

[0119] Similarly, it should be appreciated that in the foregoing description of embodiments of the present disclosure, various features are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure aiding in the understanding of one or more of the various embodiments. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed subject matter requires more features than are expressly recited in each claim. Rather, claimed subject matter may lie in less than all features of a single foregoing disclosed embodiment.

[0120] In some embodiments, the numbers expressing quantities or properties used to describe and claim certain embodiments of the application are to be understood as being modified in some instances by the term “about,” “approximate,” or “substantially.” For example, “about,” “approximate,” or “substantially” may indicate $\pm 20\%$ variation of the value it describes, unless otherwise stated. Accordingly, in some embodiments, the numerical parameters set forth in the written description and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by a particular embodiment. In some embodiments, the numerical parameters should be construed in light of the count of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of some embodiments of the application are approximations, the numerical values set forth in the specific examples are reported as precisely as practicable.

[0121] Each of the patents, patent applications, publications of patent applications, and other material, such as articles, books, specifications, publications, documents, things, and/or the like, referenced herein is hereby incorporated herein by this reference in its entirety for all purposes, excepting any prosecution file history associated with same, any of same that is inconsistent with or in

conflict with the present document, or any of same that may have a limiting effect as to the broadest scope of the claims now or later associated with the present document. By way of example, should there be any inconsistency or conflict between the description, definition, and/or the use of a term associated with any of the incorporated material and that associated with the present document, the description, definition, and/or the use of the term in the present document shall prevail.

[0122] In closing, it is to be understood that the embodiments of the application disclosed herein are illustrative of the principles of the embodiments of the application. Other modifications that may be employed may be within the scope of the application. Therefore, by way of example, but not of limitation, alternative configurations of the embodiments of the application may be utilized in accordance with the teachings herein. Accordingly, embodiments of the present application are not limited to that precisely as shown and described.

WHAT IS CLAIMED IS:

1. A power surge protection circuit, comprising:

a first surge protection module, a second surge protection module, a third surge protection module, a first filtering module, and a first residual voltage processing module; wherein

the first surge protection module is configured to cooperate with the second surge protection module to discharge an energy of a first surge generated between a positive input end of a power supply and a ground end, and cooperate with the third surge protection module to discharge an energy of a second surge generated between a negative input end of the power supply and the ground end;

the second surge protection module is configured to cooperate with the third surge protection module to discharge an energy of a third surge generated between the positive input end of the power supply and the negative input end of the power supply and generate a residual voltage;

the first filtering module is configured to filter out a noise generated by the power surge protection circuit when discharging the energy of the third surge or the energies of the first surge and the second surge; and

the first residual voltage processing module is configured to reduce the residual voltage.

2. The power surge protection circuit of claim 1, wherein

a first end of the third surge protection module is connected with the positive input end of the power supply and a first end of the second surge protection module, respectively, a second end of the third surge protection module is connected with the negative input end of the power supply, a third end of the third surge protection module is connected with a second end of the second surge protection module and a first end of the first surge protection module, respectively, and a second end of the first surge protection module is connected with the ground end;

the first surge protection module is configured to conduct a path between the first end of the second surge protection module and the second end of the first surge protection module when the first surge is generated, and conduct a path between the second end of the third surge protection module and the second end of the first surge protection module when the second surge is generated to discharge the energies of the first surge and the second surge; and

the second surge protection module is configured to conduct a path between the first end of the second surge protection module and the second end of the third surge protection module to discharge the energy of the third surge when the third surge is generated.

3. The power surge protection circuit of claim 2, wherein

the second surge protection module includes a first gas discharge tube and a first capacitor, and the first gas discharge tube and the first capacitor are connected in parallel; and

the third surge protection module includes a plurality of second gas discharge tubes and a plurality of second capacitors, the plurality of second gas discharge tubes are connected in series, an end of the plurality of second capacitors is connected with nodes of the plurality of second gas discharge tubes

connected in series, respectively, and each of the nodes connects two adjacent gas second discharge tubes of the plurality of second gas discharge tubes and a count of the plurality of second gas discharge tubes is greater than or equal to two, a difference between a count of the plurality of second capacitors and the count of the plurality of second gas discharge tubes is equal to 1.

4. The power surge protection circuit of claim 3, wherein

a first end of the first capacitor and the first gas discharge tube may be determined as the first end of the second surge protection module, and a second end of the first gas discharge tube and the first capacitor may be determined as the second end of the second surge protection module; and

the second gas discharge tubes are connected in series between the second end of the second surge protection module and the negative input end of the power supply, an end of a second gas discharge tube connected with the second end of the second surge protection module may be determined as the third end of the third surge protection module, an end of the second gas discharge tubes connected with the negative input end of the power supply may be determined as the second end of the third surge protection module, a first end of the second capacitors may be determined as the first end of the third surge protection module, and a second end of the second capacitors is connected with the nodes, respectively.

5. The power surge protection circuit of claim 1 or claim 2, wherein

the second surge protection module includes a plurality of first gas discharge tubes and a plurality of first capacitors, the plurality of first gas discharge tubes are connected in series, an end of the plurality of first capacitors is connected with nodes of the a plurality of first gas discharge tubes, respectively, and each of the nodes connects two adjacent first gas discharge tubes of the plurality of first gas discharge tubes, and a count of the plurality of first gas discharge tubes is greater than or equal to two, a difference between a count of the plurality of first capacitors and the count of the plurality of second gas discharge tubes is equal to 1; and

the third surge protection module includes a second gas discharge tube and a second capacitor, and the second gas discharge tube and the second capacitor are connected in parallel.

6. The power surge protection circuit of claim 5, wherein

the third gas discharge tubes are connected in series between the positive input end of the power supply and the third end of the third surge protection module, an end of a first gas discharge tube connected with the third end of the third surge protection module may be determined as the second end of the second surge protection module, an end of the first gas discharge tubes connected with the positive input end of the power supply and the end of the second capacitors connected with the positive input end of the power supply are determined as the first end of the second surge protection module; wherein the end of the first capacitors connected with the positive input end of the power supply is the first end of the first capacitors, and the second end of the first capacitors is connected with the nodes, respectively; and

an end of the third surge protection module where the second gas discharge tube and the second capacitor are connected may be determined as the third end of the third surge protection module, wherein the first end of the second gas discharge tube is connected with the second end of the second capacitor, a second end of the gas discharge tube may be determined as the second end of the third surge protection module, and the first end of the second capacitors may be determined as the first end of the third surge protection module.

7. The power surge protection circuit of any one of claims 2-6, wherein the first surge protection module includes a first varistor; and an end of a gas discharge tube connected with the positive input end of the power supply is connected with a first end of the first varistor, and a second end of the first varistor is connected with the ground end.

8. The power surge protection circuit of claim 7, wherein the first surge protection module further includes a second varistor; and an end of the gas discharge tube connected with the negative input end of the power supply is connected with a first end of the second varistor, and a second end of the second varistor is connected with the ground end.

9. The power surge protection circuit of any one of claims 2-6, wherein the first surge protection module includes a first varistor; and an end of the gas discharge tube connected with the negative input end of the power supply is connected with a first end of the first varistor, and a second end of the first varistor is connected with the ground end.

10. The power surge protection circuit of claim 9, wherein the first surge protection module further includes a second varistor; an end of the gas discharge tube connected with the positive input end of the power supply is connected with a first end of the second varistor, and a second end of the second varistor is connected with the ground end.

11. The power surge protection circuit of any one of claims 1-10, wherein a first end of the first filtering module is connected with the positive input end of the power supply, a second end of the first filtering module is connected with the negative input end of the power supply, a third end of the first filtering module is connected with a first end of the first residual voltage processing module, and a fourth end of the first filtering module is connected with a second end of the first residual voltage processing module.

12. The power surge protection circuit of claim 11, wherein

the first filtering module includes a third capacitor and a common mode inductor;

a first end of the third capacitor may be determined as the first end of the first filtering module and is connected with a first end of the common mode inductor, a second end of the second capacitor may be determined as the second end of the first filtering module and is connected with a second end of the common mode inductor, a third end of the common mode inductor may be determined as the third end of the first filtering module, and a fourth end of the common mode inductor may be determined as the fourth end of the first filtering module.

13. The power surge protection circuit of any one of claims 1-12, wherein

the first residual voltage processing module includes a first bidirectional transient suppression diode; and

a first end of the first bidirectional transient suppression diode may be determined as the first end of the first residual voltage processing module, and a second end of the first bidirectional transient suppression diode may be determined as the second end of the first residual voltage processing module.

14. The power surge protection circuit of any one of claims 1-13, further comprising:

a second filtering module configured to reduce an electromagnetic radiation generated by the power surge protection circuit when discharging an energy of a differential mode; and

a second residual voltage processing module configured to reduce the residual voltage that is reduced by the first residual voltage processing module

15. The power surge protection circuit of claim 14, wherein

a first end of the second filtering module is connected with the first end of the first residual voltage processing module, a second end of the second filtering module is connected with the second end of the first residual voltage processing module, a third end of the second filtering module is connected with a first end of the second residual voltage processing module, and a fourth end of the second filtering module is connected with a second end of the second residual voltage processing module.

16. The power surge protection circuit of claim 14 or 15, the second filtering module including: a fourth capacitor, a fifth capacitor, and a differential mode inductor; wherein

a first end of the third capacitor may be determined as the first end of the second filtering module and is connected with a first end of the differential mode inductor, a second end of the third capacitor may be determined as the second end of the second filtering module, a first end of the fourth capacitor may be determined as the third end of the second filtering module and is connected with a second end of the differential mode inductor, and a second end of the fourth capacitor may be determined as the fourth end of the second filtering module and is connected with the second end of the third capacitor.

17. The power surge protection circuit of any one of claims 14-16, the second residual voltage

processing module including a second bidirectional transient suppression diode; wherein

a first end of the second bidirectional transient suppression diode may be determined as the first end of the second residual voltage processing module, and a second end of the second bidirectional transient suppression diode may be determined as the second end of the second residual voltage processing module.

18. The power surge protection circuit of any one of claims 1-17, further comprising a first fuse and/or a second fuse; wherein the first end of the first filtering module is connected with the positive input end of the power supply through the first fuse, and the second end of the first filtering module is connected with the negative input end of the power supply through the second fuse.

19. A device, comprising:

a power supply; and

the power surge protection circuit of any one of claims 1-18, wherein the power surge protection circuit is configured to perform a surge protection on the power supply.

100

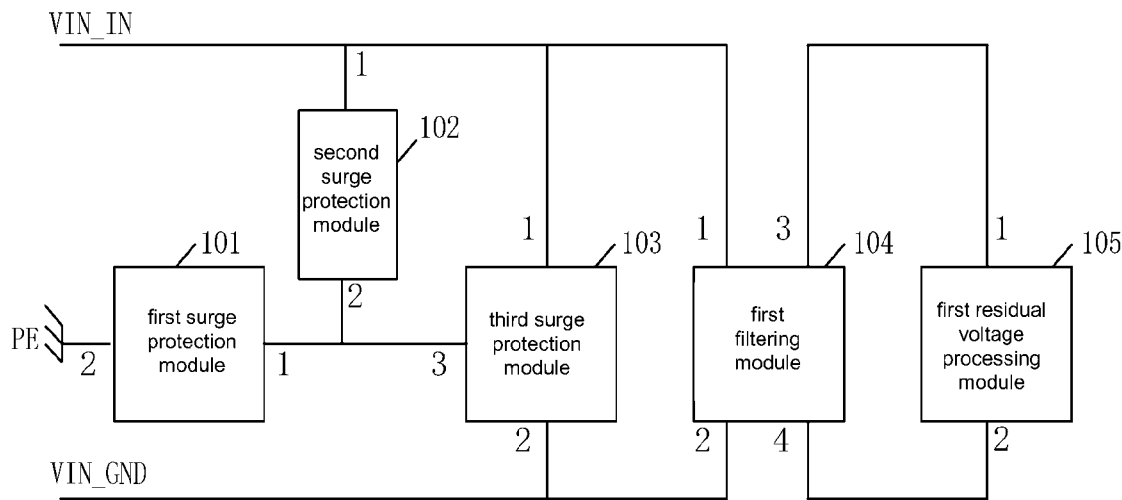


FIG. 1

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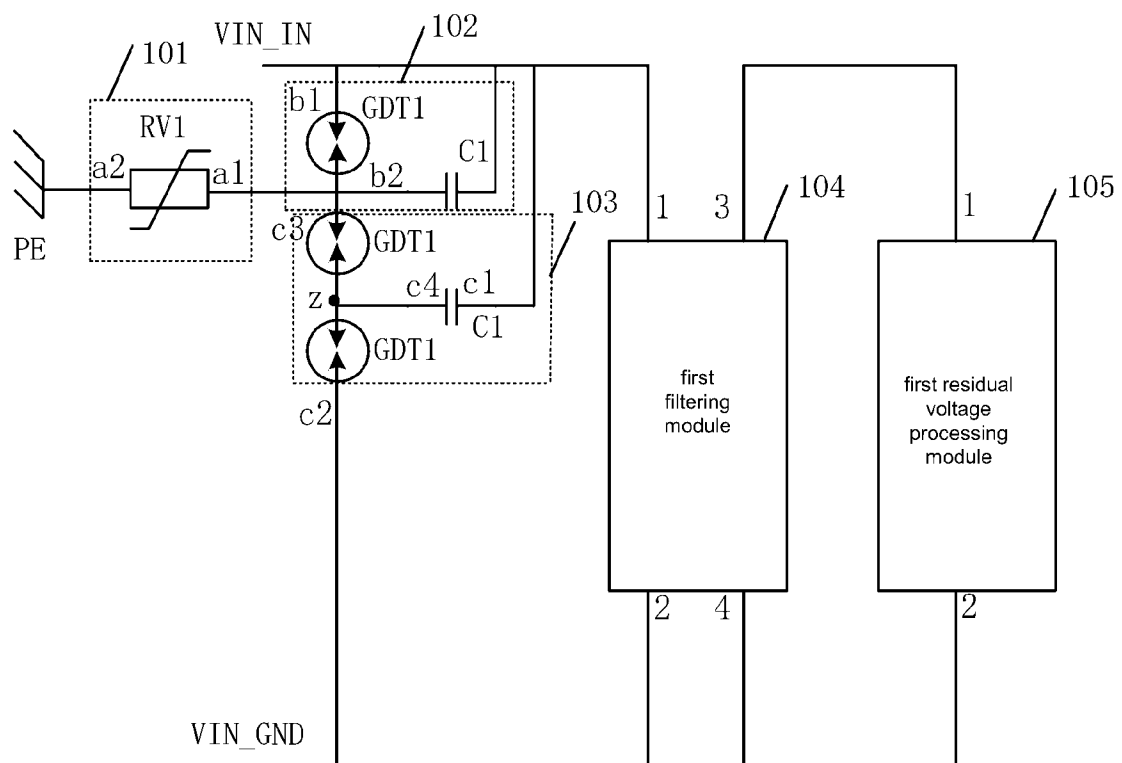


FIG. 2A

200

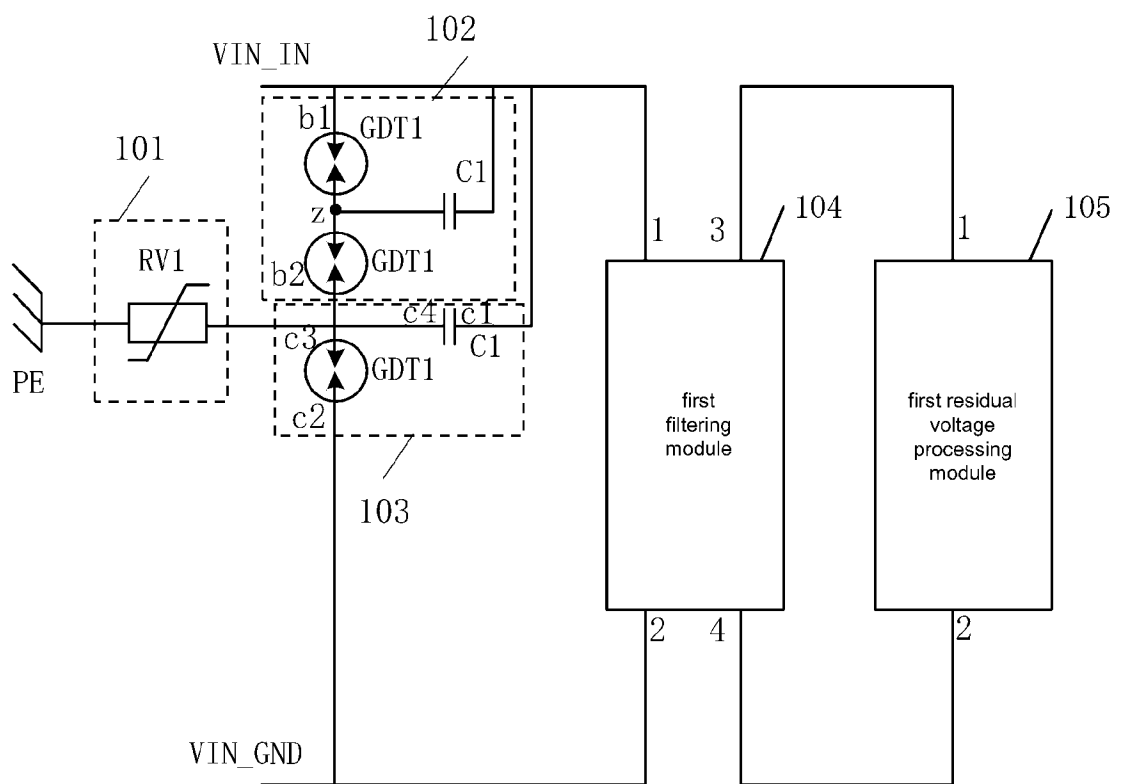


FIG. 2B

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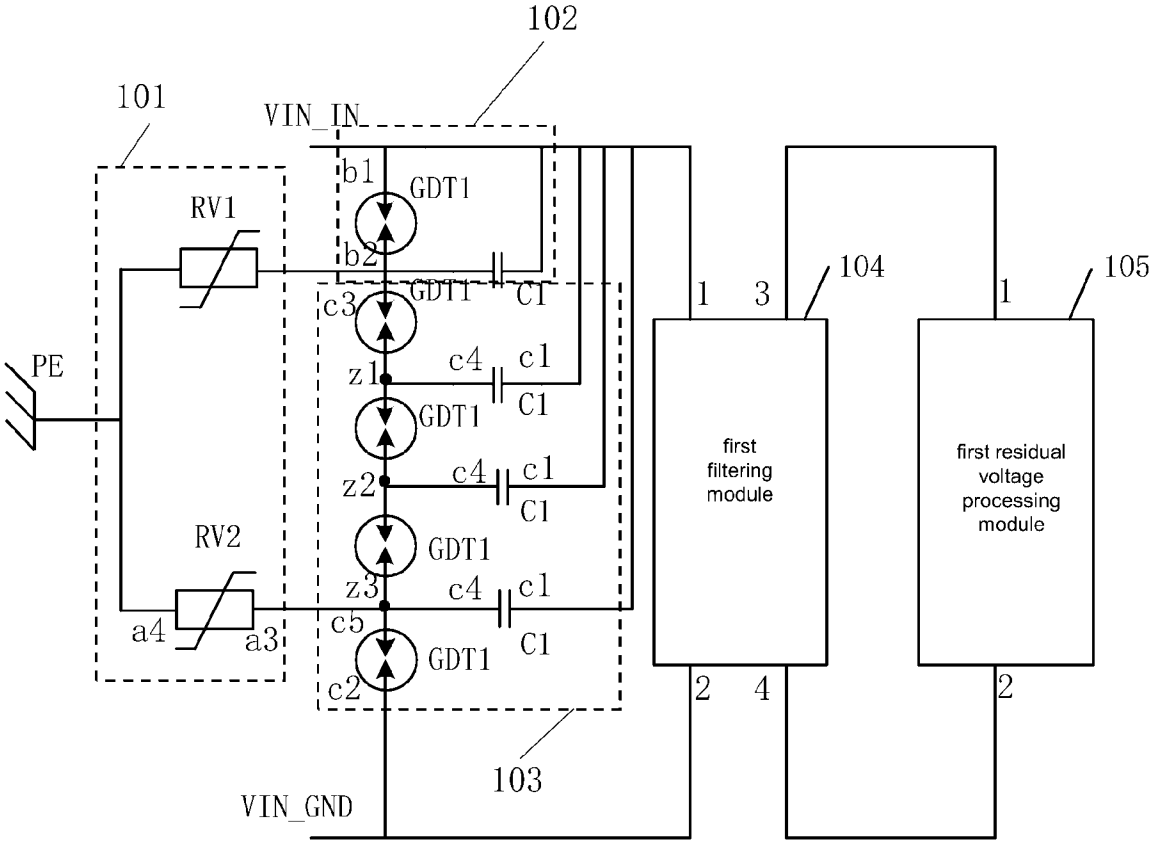


FIG. 3A

300

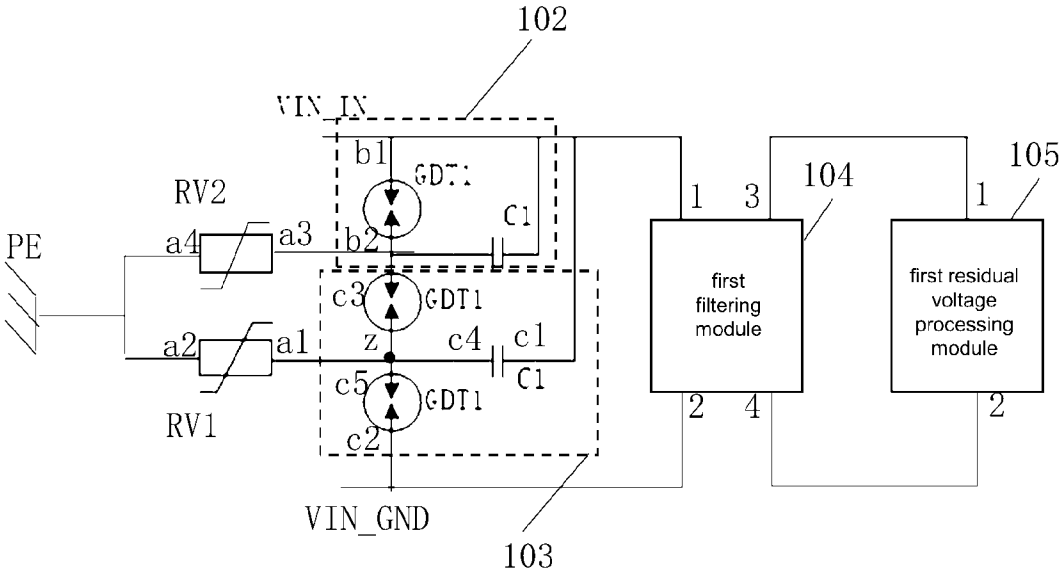


FIG. 3B

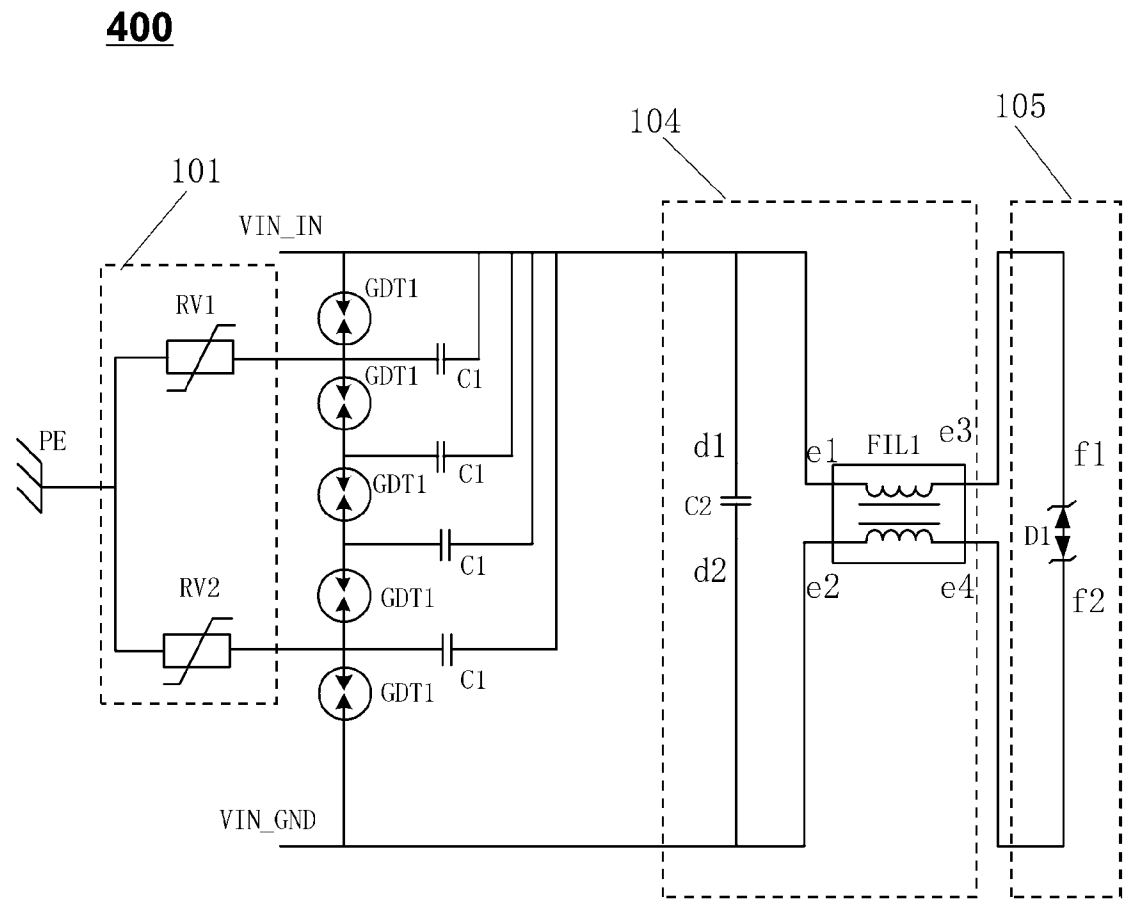


FIG. 4

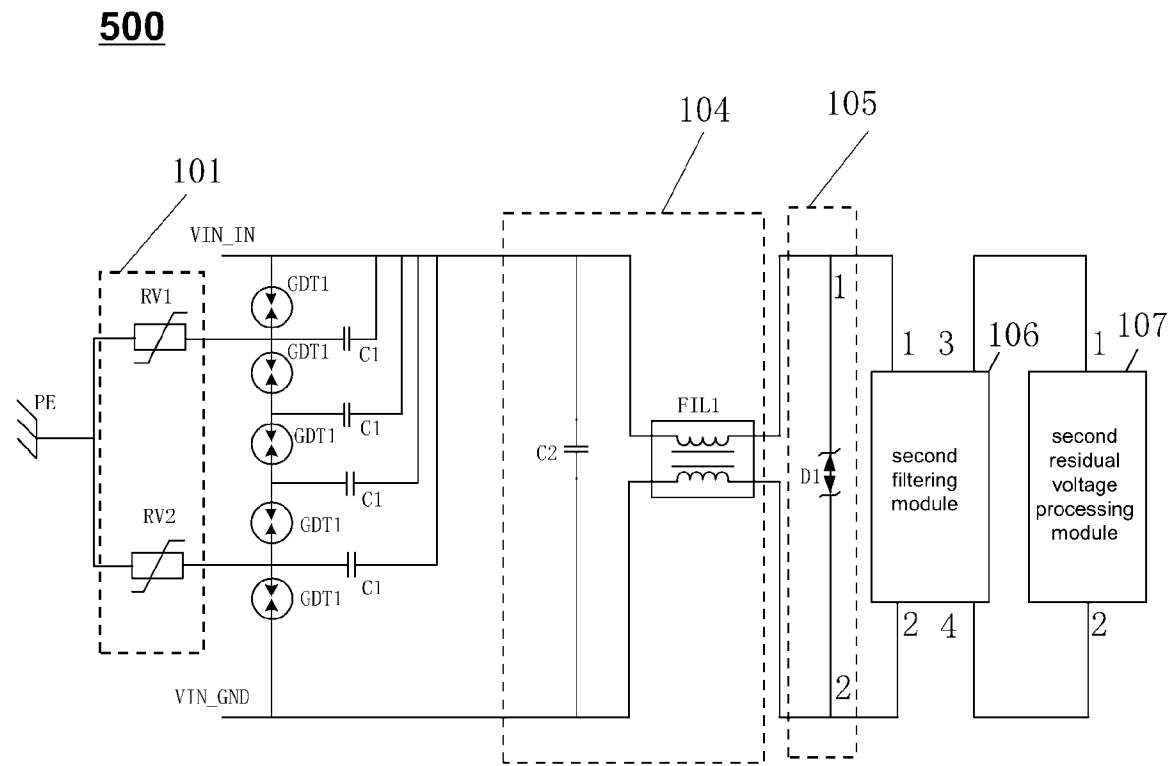


FIG. 5

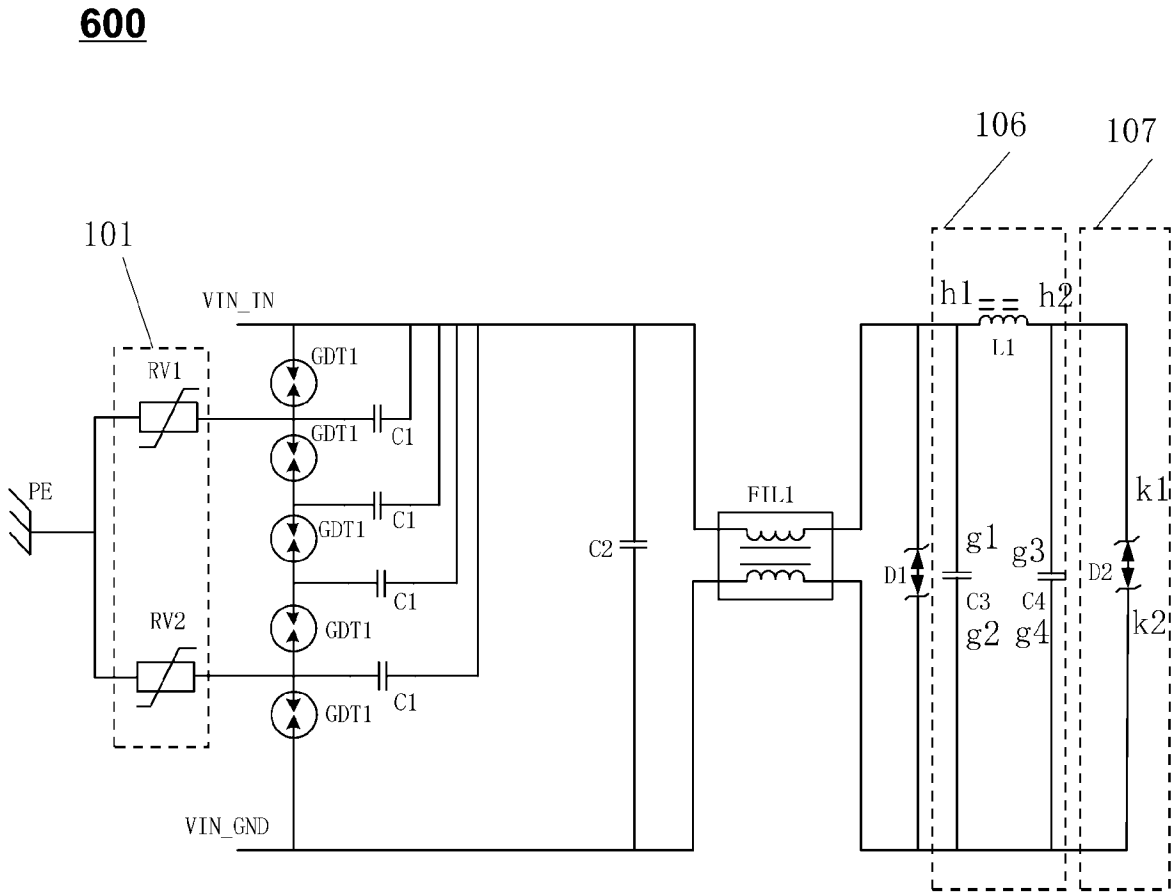


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/085907

A. CLASSIFICATION OF SUBJECT MATTER

H02M1/32(2007.01)i; H02M1/12(2006.01)n; H02H7/12(2006.01)n

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)

IPC: H02M, H02H

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)

VEN, WOTXT, EPTXT, USTXT, CNKI, IEEE: discharge tube?, series, capacitor?, filter+, transient 2w suppression, TVS, varistor?, MOV

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 116613978 A (ZHEJIANG DAHUA TECHNOLOGY CO., LTD.) 18 August 2023 (2023-08-18) description, paragraphs 46-80 and figures 1-7	1-19
Y	CN 102709902 A (HUAWEI TECHNOLOGIES CO., LTD.) 03 October 2012 (2012-10-03) description, paragraphs 2, 15-21, 33-42 and figures 1, 2, 5, 6	1-19
Y	CN 202693002 U (SHENZHEN EXSAF ELECTRONICS CO., LTD.) 23 January 2013 (2013-01-23) description, paragraphs 19-36 and figures 1-2	1-19
Y	CN 201975784 U (EPCOS ELECTRONIC (XIAOGAN) CO., LTD.) 14 September 2011 (2011-09-14) description, paragraphs 13-18 and figure 2	1-19
Y	CN 217769488 U (CHENGDU XINXIN SHENFENG ELECTRONIC TECHNOLOGY CO., LTD.) 08 November 2022 (2022-11-08) description, paragraphs 29-33 and figure 1	1-19
A	US 2012013271 A1 (LEI, Xishe et al.) 19 January 2012 (2012-01-19) the whole document	1-19

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance
“D” document cited by the applicant in the international application
“E” earlier application or patent but published on or after the international filing date
“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
“O” document referring to an oral disclosure, use, exhibition or other means
“P” document published prior to the international filing date but later than the priority date claimed

“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

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

17 July 2024

Date of mailing of the international search report

23 July 2024

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/085907

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	116613978	A	18 August 2023	None			
CN	102709902	A	03 October 2012	None			
CN	202693002	U	23 January 2013	None			
CN	201975784	U	14 September 2011	None			
CN	217769488	U	08 November 2022	None			
US	2012013271	A1	19 January 2012	US	8456138	B2	04 June 2013