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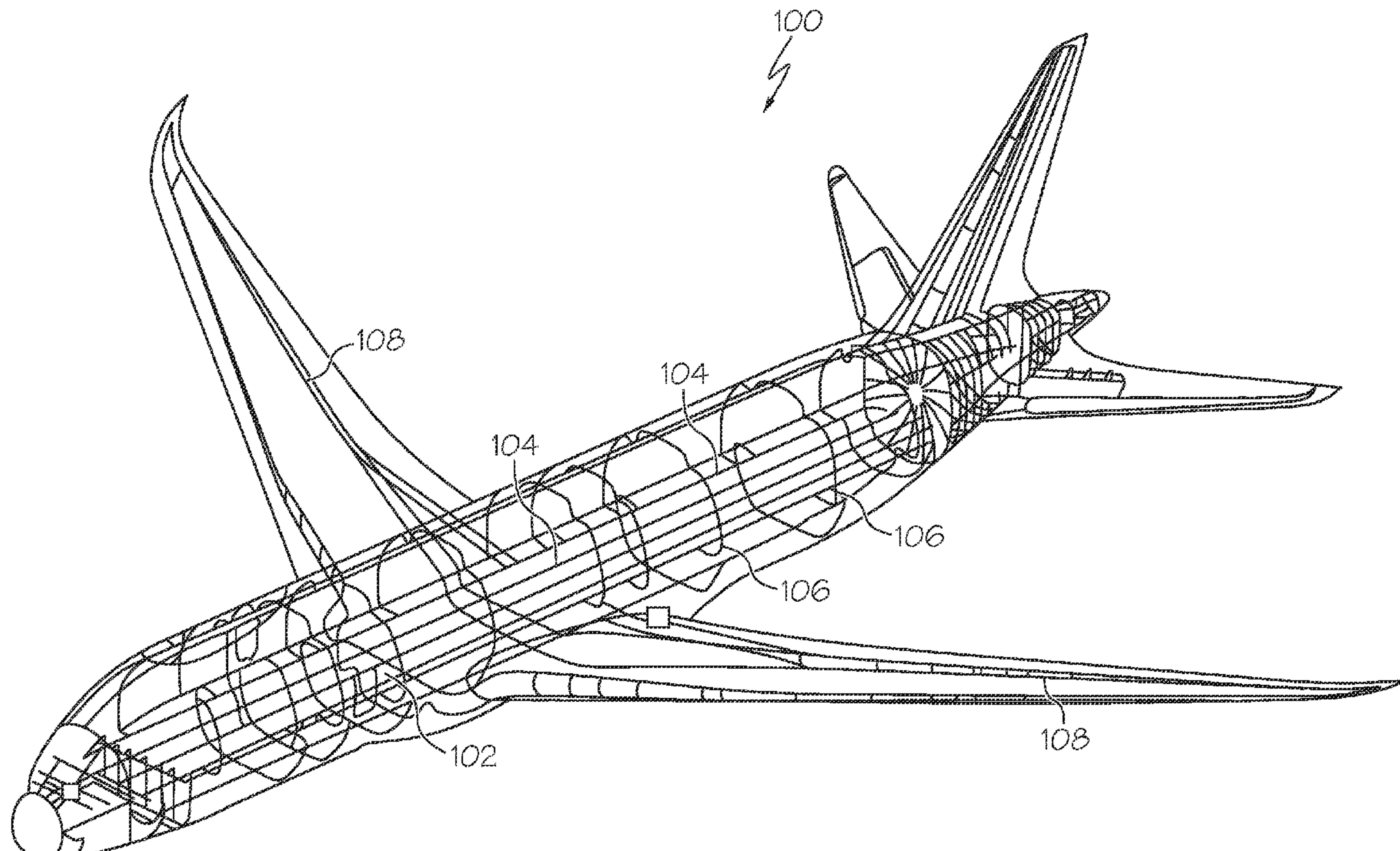
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(54) **Titre : PROCEDE ET APPAREIL DE DETECTION DE FOUDROIEMENT**
(54) **Title: METHOD AND APPARATUS FOR DETECTING A LIGHTNING STRIKE**



(57) **Abrégé/Abstract:**

Described herein is a self-powered system for detecting a current spike. The current spike is delivered through a current return network that energizes a resonant circuit to produce an alternating electrical output. The output is rectified by a rectifier into direct output that is then transferred to an integrator circuit. The integrator circuit slowly builds to and dissipates from a voltage threshold corresponding to an output transistor. When the output transistor is triggered by the voltage threshold this trigger is communicated to a fault monitoring software that recognizes the current spike.

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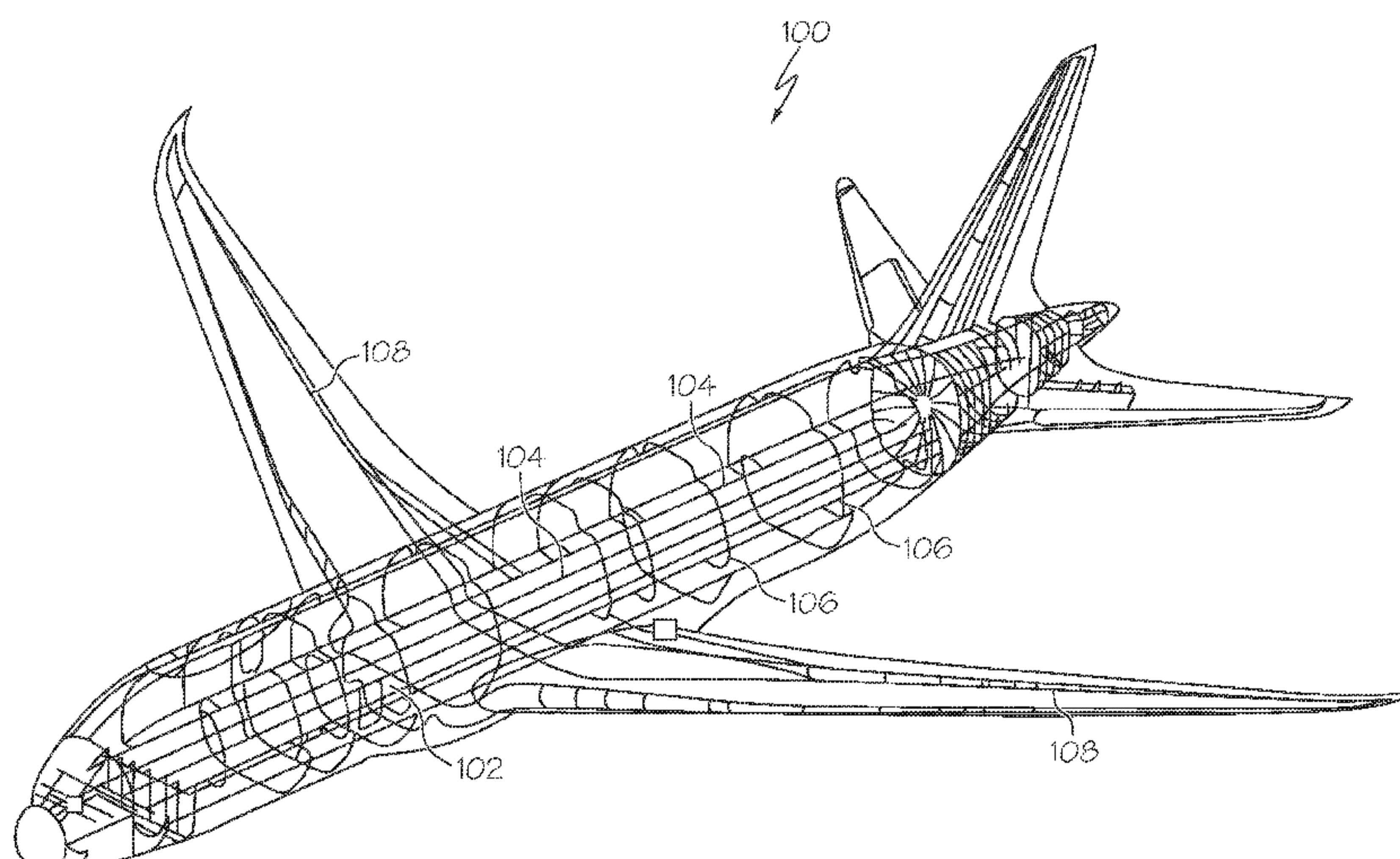


FIG. 1

WO 2013/062706 A1

(57) Abstract: Described herein is a self-powered system for detecting a current spike. The current spike is delivered through a current return network that energizes a resonant circuit to produce an alternating electrical output. The output is rectified by a rectifier into direct output that is then transferred to an integrator circuit. The integrator circuit slowly builds to and dissipates from a voltage threshold corresponding to an output transistor. When the output transistor is triggered by the voltage threshold this trigger is communicated to a fault monitoring software that recognizes the current spike.

METHOD AND APPARATUS FOR DETECTING A LIGHTNING STRIKE**BACKGROUND**

The current disclosure relates to a current spike detector and more specifically to an electrical circuit for detecting lightning strikes in aircraft.

5 Lightning strikes on aircraft are relatively rare events, yet occur with sufficient frequency and are sufficiently damaging to mechanical and electrical systems that lightning strike prevention and mitigation are important components within an aircraft.

10 Reporting of lightning strikes, their location, intensity, and effects are presently handled by the aircraft and ground crews. The aircraft crew is responsible for determining whether the aircraft has been struck, typically through visual confirmation or short-lived electrical interference of instrumentation or lighting. The ground crew is then tasked to determine the severity, location, and impact of the lightning strike on the flightworthiness of the aircraft. However, because this system is based on an initial determination by the aircraft crew, this system of reporting may result in over or under reporting of strikes.

15 When lightning strikes an aircraft a large amount of current passes through the aircraft. In a metal skinned aircraft, this current is predominantly carried over the exterior surfaces of the aircraft. However, aircraft using composite construction often incorporate a lightning or current return network of electrical connectors, installed within the aircraft, to carry the large currents which result from lightning strikes. In such composite aircraft, this current may be directed through a current return network that reduces the chance of electrical systems being damaged by the current spike. However, some temporary electrical system failures may still occur. When these systems recover, they issue a warning, typically to the cockpit although they may be recorded elsewhere, that must be checked by a maintenance crew when the aircraft is next grounded.

20 Some of these electrical system warnings may be so-called "nuisance warnings" that occur due to the system resetting because of the lightning strike rather than any problem with the system. However, these systems will still require manual resetting by a maintenance worker to reset the warnings and determine if the fault was due to the lightning strike event or a problem in the affected system.

25 Therefore, there is recognized a need in the art for a lightning detection system.

SUMMARY

In one embodiment there is provided a self-powered system for detecting a lightning strike. The system includes a current return network for receiving and dissipating the lightning strike. The system further includes a resonant circuit comprising an inductor and a capacitor connected in parallel. The inductor is coupled to the current return network to enable current conducted by the current return network to excite the resonant circuit to produce an alternating current. The system further includes a rectifier for rectifying the alternating current into a direct current, an integrator circuit configured to integrate the direct current to produce a voltage, and an output switch triggered by the integrator circuit when the voltage reaches a voltage threshold and configured to produce a signal indicating the occurrence of the lightning strike.

The current return network may include an electrically conductive path within an aircraft.

The integrator circuit may include an integrating capacitor.

The integrating capacitor may be charged by the direct current output.

The integrating capacitor may be charged for several seconds.

In another embodiment there is provided a method of detecting a voltage spike in a current return network. The method involves the steps of inductively coupling an inductor of a resonant circuit comprising a capacitor connected in parallel with the inductor with current conducted by the current return network to produce an alternating current. The method further involves rectifying the alternating current to produce a direct current, integrating the direct current with an integrator circuit to produce a voltage, activating a switch when the voltage reaches a threshold voltage, and producing a signal indicative of the voltage spike, in response to activating the switch.

Rectifying may involve subjecting the alternating current to a half-wave rectifier.

Inductively coupling may involve inductively coupling a ferrite cored inductor to the current return network.

The method may further involve selectively attaching and removing the ferrite core to and from the current return network.

Attaching may involve clamping the ferrite core to the current return network.

The switch may include a normally open n-type Metal Oxide Semiconductor Field Effect Transistor (n-MOSFET).

The method may further involve coupling the switch to a remote fault monitor to selectively draw current from the remote fault monitor through the switch.

The method may further involve detecting current flow from the remote fault monitor to detect a change in state of the signal.

5 The method may further involve bleeding off a voltage on a capacitor of the integrator circuit after the change in state of the signal is detected.

In another embodiment there is provided a self-powered system for detecting a lightning strike including a current return network receiving and dissipating the lightning strike, a resonant circuit having a transformer in communication with the current return network and providing an 10 alternating electrical output, and a rectifier for rectifying the alternating electrical output into a direct electrical output. The self-powered system for detecting a lightning strike further includes an integrator circuit that builds to a voltage threshold when the direct electrical output is received, including a second capacitor, an output transistor triggered to change state by the integrator circuit when the voltage threshold is reached for communicating a signal with a fault 15 monitoring software, and external monitoring equipment connected to the output transistor by a diode such that current flows from the external monitoring equipment to the output transistor.

The current return network may include an electrically conductive path within an aircraft.

The resonant circuit may include an inductor and a first capacitor.

20 In accordance with another embodiment there is provided an aircraft including the any of the systems described above.

In another embodiment there is provided a method of detecting a lightning strike in a current return network of an aircraft. The method involves the steps of providing a ferrite core in inductive communication with the current return network, providing a detection circuit having a resonant circuit in inductive communication with the ferrite core, an integrator circuit, and a 25 transistor, and providing external monitoring equipment connected to the transistor by a diode such that current flows from the external monitoring equipment to the transistor. The method further involves the steps of inductively energizing the resonant circuit by a current spike in the current return network to provide an alternating current, rectifying the alternating current by a rectifier, charging a second capacitor in the integrator circuit by the rectified current to a 30 threshold voltage level, changing the transistor's state when the threshold voltage level is reached, and detecting the change in state as indicative of the lightning strike.

The rectification may be by means of a half-wave rectifier.

The resonant circuit may include an inductor and a first capacitor.

The current return network, the inductor, and the ferrite core may form a transformer.

The ferrite core may be selectively removable from the current return network.

5 The method may further involve the step of attaching the ferrite core to the current return network.

Current flow from the external monitoring equipment through the transistor may be used to detect the change in state.

10 The features, functions, and advantages that have been discussed can be achieved independently in various embodiments of the present invention or may be combined in yet other embodiments further details of which can be seen with reference to the following description and drawings.

DESCRIPTION OF DRAWINGS

Fig. 1 is a perspective view of an aircraft showing a current return network.

15 Fig. 2 is a schematic view showing the attachment between the current return network and a detection circuit.

Fig. 3A is a schematic view of the detection circuit.

Fig. 3B is a schematic view of an alternative embodiment of the detection circuit.

DESCRIPTION

20 Fig. 1 shows a perspective view of an aircraft 100 cutaway to show a current return network 102 that may include longitudinal 104 and lateral 106 electrically conductive elements extending along a substantial portion of the aircraft 100. The current return network 102 also includes current carrying paths 108 extending through the wings and tail of the aircraft 100. The longitudinal 104 and lateral 106 elements as well as the current carrying paths 108 may be low resistance electrical wires, metal, or other conductive material including but not limited to aircraft structural elements, hydraulic lines, or dedicated current return components. These elements 104, 106, 108 of the current return network 102 may be connected to one another to provide a number of redundant electrical pathways that may be adapted to carry fault current, provide grounding, carry lightning current, provide electromagnetic shielding, minimize 25 resistance and voltage differentials and provide a bleed path for electrostatic charge.

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30

As shown in Fig. 2, a lightning strike detection device 112 may include a clamp-on magnetically permeable core with windings 114 that is secured about a portion of the current return network 102 and a lightning strike detection circuit 116 in communication with the ferrite core 114. The clamp-on ferrite core 114 is a closed loop of high-magnetic permeability material, such as iron, ferrous-oxide coated ceramics, or other material. The ferrite core 114 may be a removable or permanent device attached to the current return network.

Fig. 3A illustrates the lightning strike detection circuit 116 in further detail. As shown in this figure, the circuit 116 may include a resonant circuit 118, an integrator circuit 120, and a transistor 122 connected to external monitoring equipment 124. The resonant circuit 118 may include an inductor 126 and first capacitor 128 in parallel that is in parallel with and coupled to the integrator circuit 120 by a rectifying diode 130. The integrator circuit 120 includes a resistor 132 and second capacitor 134 in parallel. The integrator circuit 120 is tied to the gate 136 of the transistor 122 and the transistor source 138 goes to ground. The transistor itself 122 is shown as a normally-open enhancement-mode n-type Metal Oxide Semiconductor Field Effect Transistor (n-MOSFET) that provides a voltage controlled current source between the external monitoring equipment 124 and ground. Electromagnetic interference (EMI) reduction elements are provided in the form of a zener diode 142 and drain diode 144 that reduce the chance of current feedback or voltage spikes that may damage the circuit 116.

According to one embodiment, a number of lightning strike detection devices 112 are positioned about the current return network 102 so as to capture a lightning strike event. With reference to Fig. 2, the devices 112 would preferably be positioned in the Zone 3 areas and may be positioned in Zone 1 or 2 areas such as on or near the engine nacelles or along the aircraft fuselage.

With reference to Fig. 2, the operation of the lightning strike device 112 will be described in further detail. As will be appreciated, when there is no lightning strike event, the lightning detection circuit 116 will remain in an unpowered state. However, when there is a lightning strike event, the circuit will be energized to indicate the event. After the event has been indicated, the circuit will reset to an unpowered state.

When lightning strikes the aircraft, a current spike lasting from 1-50 μ s is transferred to the current return network 102. The current return network 102 forms at least one loop around the ferrite core 114 and the inductor 126 forms a number of loops about the ferrite core 114, thus forming a transformer so that when a current pulse passes through the current return network 102, the inductor 126 generates a complementary current.

The inductor 126 and first capacitor 128 that form the resonant circuit 118 will create an alternating current output that energizes the circuit 116. The current output from the resonant circuit 118 is rectified by the rectifying diode 130 to a half-wave output before being transferred to the integrator circuit 120.

5 The integrator circuit 120 provides a slow charge and discharge for the second capacitor 134, which preferably maintains the voltage difference across the capacitor at a threshold level for several seconds so the capacitor becomes completely charged. The integrator circuit provides hold time and automatic resetting for the lightning indication to remain active even if the external monitoring equipment 124 is itself upset by the event.

10 When the second capacitor 134 is at a threshold level measured by the gate threshold of the transistor 122, the circuit between the source 138 and drain 140 is closed, allowing current to flow through the transistor from the external monitoring equipment 124 to ground. The external monitoring equipment 124 is an external monitoring apparatus that may be installed in the aircraft, and may be a standard aircraft equipment interface, such as an open/ground discrete 15 which senses the electrical open/ground discrete signal made by the circuit 116 and then uses this for fault or maintenance indication logic.

The zener diode 142 ensures that the voltage from the transistor gate to source does not reach a level that might damage the transistor 122 or other components.

20 The drain diode 144 is positioned between the external monitoring equipment 124 and transistor 122 and allows current to flow from the external monitoring equipment 124 through the transistor. This arrangement ensures that current cannot flow from the transistor 122 to the external monitoring equipment 124 and cause damage in case of a current spike in the ground.

25 Other improvements to the above-described electrical circuit are also contemplated. According to the embodiment illustrated, the circuit includes an n-MOSFET transistor 122 that is normally open and closes when a positive voltage is applied at the gate 136, allowing current to flow between the source 138 and drain 140. However, it is contemplated that a normally closed depletion mode MOSFET may be substituted for the normally open enhancement mode transistor 122.

30 The rectifying diode 130 is shown as a single diode in series between the tank circuit and integrator circuit. This half-wave rectifier only passes half of the resonant waveform generated by the resonant circuit 118 and therefore the amount of energy passed is reduced. However, this diode may be replaced with a full wave rectifier, such as a diode bridge, or other type of rectifier if additional energy is required.

The circuit 116 has also been described as including EMI protection elements such as the zener diode 142 and drain diode 144. These elements are included to provide protection against voltage overload of the transistor 122 (zener diode 142) or current feedback to the external monitoring equipment 124. However, these elements are not necessary to operation of the circuit 5 and may be omitted. Alternative protective elements may be included either in lieu of or in addition to these protective elements.

The resonant circuit 118 provides an alternating current based on the lightning strike waveform, but is not necessary to provide a voltage differential to the integrator circuit 120. A current spike in the current return network 102 would produce a corresponding voltage spike in 10 the inductor 126 that could be used to drive the transistor 122. However, the resonant circuit 118 provides the additional advantage of providing a bandlimit function to reduce the sensitivity of the circuit to radio frequency (RF) noise, for example from precipitation static or other RF noise.

As a passive element with a single wire connection (current return network 112), the addition of a built in test for the detection circuit 116 may not be appropriate. The test function 15 may be accomplished by the addition of a second set of windings on the ferrite core 114 that can provide a pulse to the circuit 116 to simulate a lightning strike. This would serve as an effective test to determine that the system is functioning properly.

As described with reference to Fig. 1, the current return network 102 may serve as a ground for the electrical components of the aircraft. However, the surge from a lightning strike 20 through the current return network 102 is often what causes electrical failures in various systems of the aircraft. Therefore, it may be undesirable to use the current return network 102 as a ground for the lightning strike detection circuit 116. According to one embodiment shown in Fig. 3A the external monitoring equipment 124 is connected to a ground, such as the current return network 102, and the lightning strike detection circuit 116 is connected to an independent 25 ground. Fig. 3B shows an alternative arrangement where the lightning strike detection circuit 116 and external monitoring equipment share a common ground 146, which may be an independent ground.

While the method and forms of apparatus disclosed herein constitute preferred aspects of the disclosed lightning detection apparatus and method, other methods and forms of apparatus 30 may be employed without departing from the scope of the invention.

EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A self-powered system for detecting a lightning strike, the system comprising:

5 a current return network for receiving and dissipating the lightning strike;

10 a resonant circuit comprising an inductor and a capacitor connected in parallel, the inductor being coupled to the current return network to enable current conducted by the current return network to excite the resonant circuit to produce an alternating current;

15 a rectifier for rectifying the alternating current into a direct current;

20 an integrator circuit configured to integrate the direct current to produce a voltage; and

an output switch triggered by the integrator circuit when the voltage reaches a voltage threshold and configured to produce a signal indicating the occurrence of the lightning strike.

2. The system of claim 1, wherein the current return network includes an electrically conductive path within an aircraft.

25 3. The system of claim 1 or 2 wherein the integrator circuit includes an integrating capacitor.

4. The system of claim 3 wherein the integrating capacitor is charged by the direct current output.

5. The system of claim **3** or **4** wherein said integrating capacitor is charged for several seconds.

6. A method of detecting a voltage spike in a current return network, the method
5 comprising:

inductively coupling an inductor of a resonant circuit comprising a capacitor connected in parallel with the inductor with current conducted by the current return network to produce an alternating current;

10

rectifying the alternating current to produce a direct current;

integrating the direct current with an integrator circuit to produce a voltage;

15

activating a switch when the voltage reaches a threshold voltage; and

producing a signal indicative of the voltage spike, in response to activating the switch.

20 7. The method of claim **6**, wherein rectifying comprises subjecting the alternating current to a half-wave rectifier.

8. The method of claim **6** or **7**, wherein inductively coupling comprises inductively coupling a ferrite cored inductor to the current return network.

25

9. The method of claim **8**, further comprising selectively attaching and removing the ferrite core to and from the current return network.

30 10. The method of claim **9**, wherein attaching comprises clamping the ferrite core to the current return network.

11. The method of any one of claims **6** to **10**, wherein the switch includes a normally open n-type Metal Oxide Semiconductor Field Effect Transistor (n-MOSFET).
12. The method of claim **6**, further including coupling the switch to a remote fault monitor to selectively draw current from the remote fault monitor through the switch.
13. The method of claim **12**, further including detecting current flow from the remote fault monitor to detect a change in state of the signal.
- 10 14. The method of claim **13**, further comprising bleeding off a voltage on a capacitor of the integrator circuit after the change in state of the signal is detected.
15. A self-powered system for detecting a lightning strike comprising:
 - 15 a current return network receiving and dissipating the lightning strike;
 - 15 a resonant circuit having a transformer in communication with the current return network and providing an alternating electrical output;
 - 20 a rectifier for rectifying the alternating electrical output into a direct electrical output;
 - 20 an integrator circuit that builds to a voltage threshold when the direct electrical output is received, including a second capacitor;
 - 25 an output transistor triggered to change state by the integrator circuit when the voltage threshold is reached for communicating a signal with a fault monitoring software; and
 - 30 external monitoring equipment connected to the output transistor by a diode such that current flows from the external monitoring equipment to the output transistor.

16. The system of claim 15, wherein the current return network comprises an electrically conductive path within an aircraft.
- 5 17. The system of claim 15 or 16, wherein the resonant circuit includes an inductor and a first capacitor.
18. An aircraft comprising the system of any one of claims 15 to 17.
- 10 19. A method of detecting a lightning strike in a current return network of an aircraft, the method comprising the steps of:
 - 15 providing a ferrite core in inductive communication with the current return network;
 - 15 providing a detection circuit having a resonant circuit in inductive communication with the ferrite core, an integrator circuit, and a transistor;
 - 20 providing external monitoring equipment connected to the transistor by a diode such that current flows from the external monitoring equipment to the transistor;
 - 25 inductively energizing the resonant circuit by a current spike in the current return network to provide an alternating current;
 - 25 rectifying the alternating current by a rectifier;
 - 30 charging a second capacitor in the integrator circuit by the rectified current to a threshold voltage level;
 - 30 changing the transistor's state when the threshold voltage level is reached; and

detecting the change in state as indicative of the lightning strike.

20. The method of claim **19**, wherein the rectification is by means of a half-wave rectifier.

5 21. The method of claim **19** or claim **20**, wherein the resonant circuit comprises an inductor and a first capacitor.

22. The method of claim **21**, wherein the current return network, the inductor, and the ferrite core form a transformer.

10

23. The method of any one of claims **19** to **22**, wherein the ferrite core is selectively removable from the current return network.

15

24. The method of claim **23**, further comprising the step of attaching the ferrite core (**114**) to the current return network.

25. The method of claim **24**, wherein current flow from the external monitoring equipment through the transistor is used to detect the change in state.

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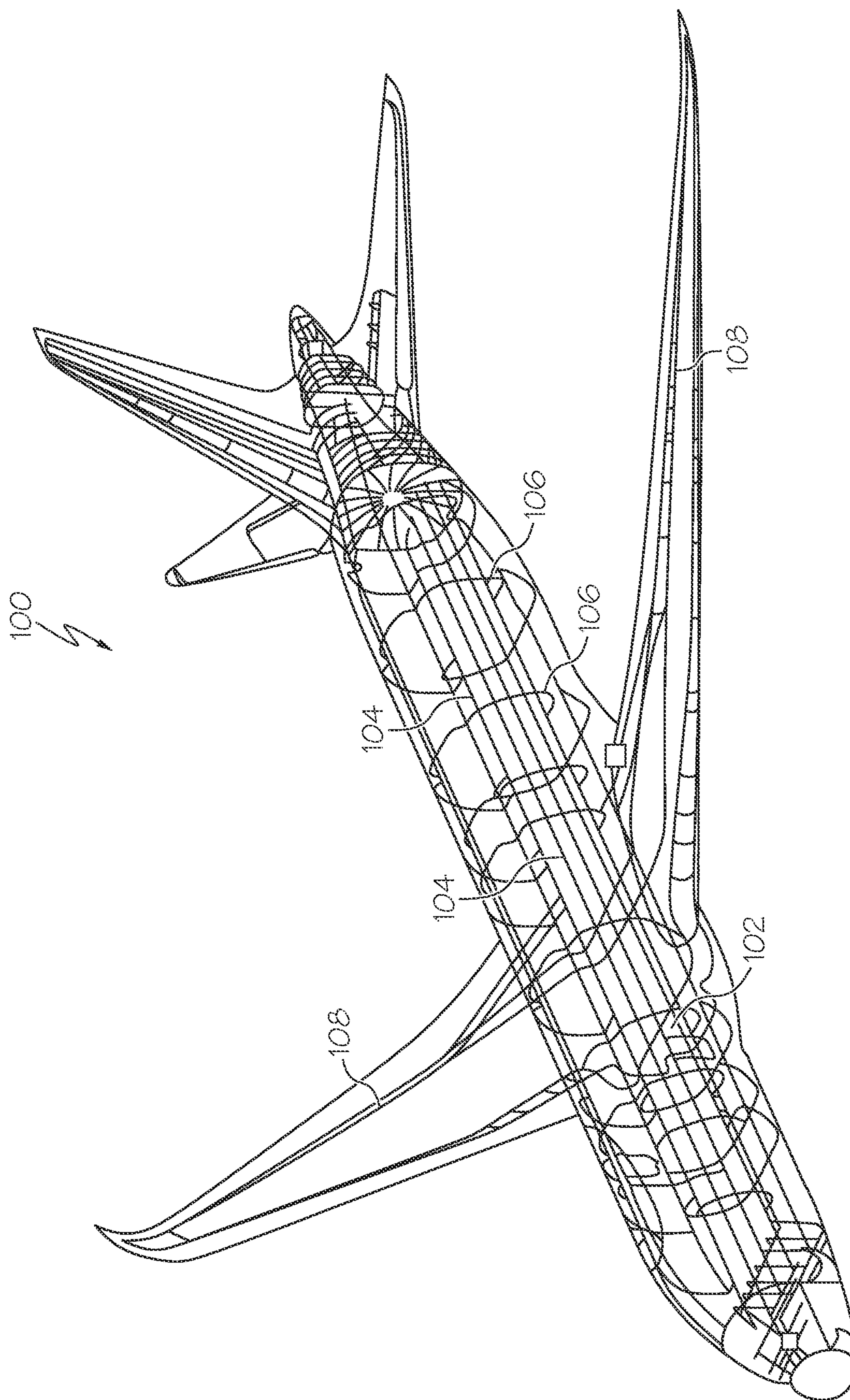


FIG. 1

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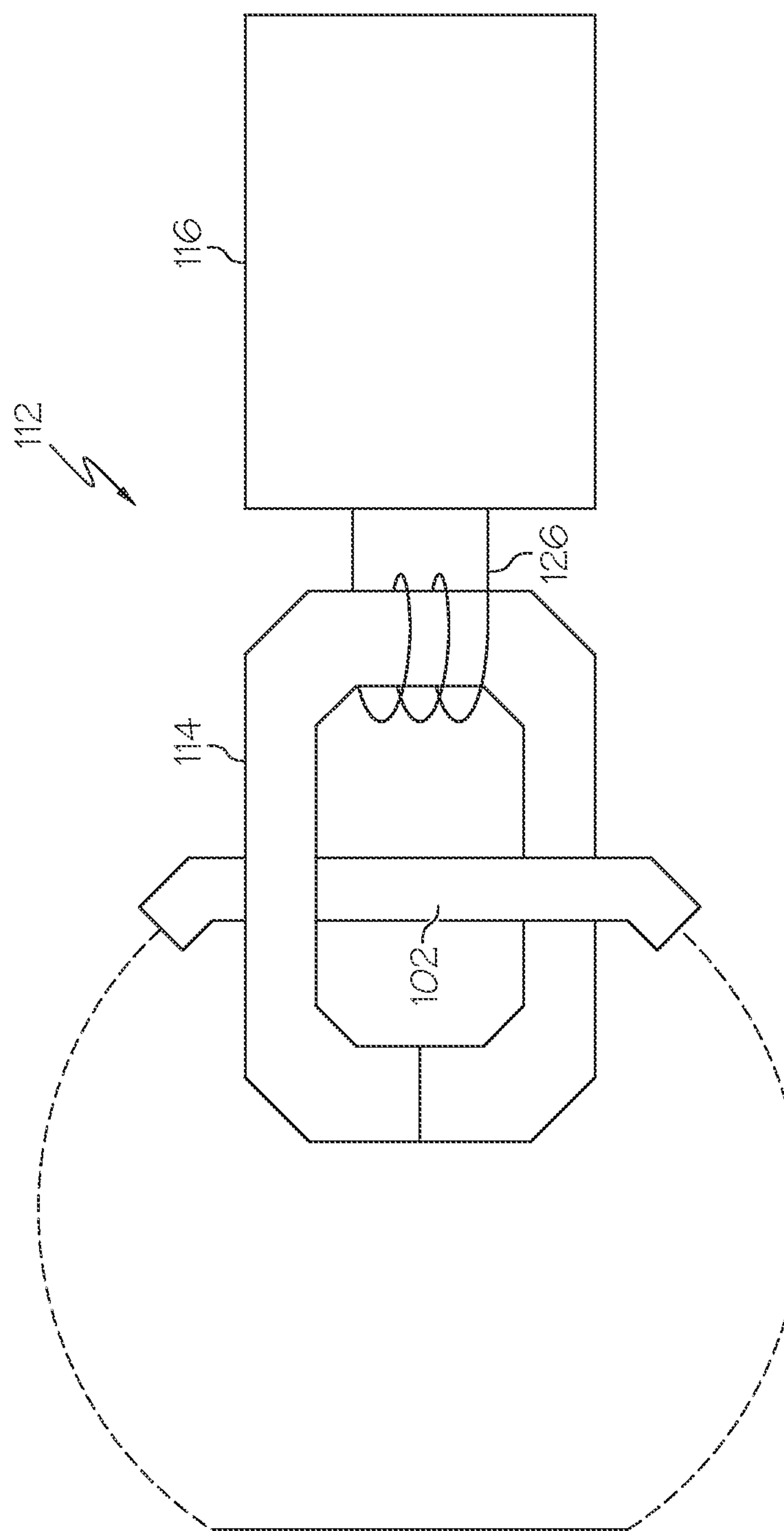


FIG. 2

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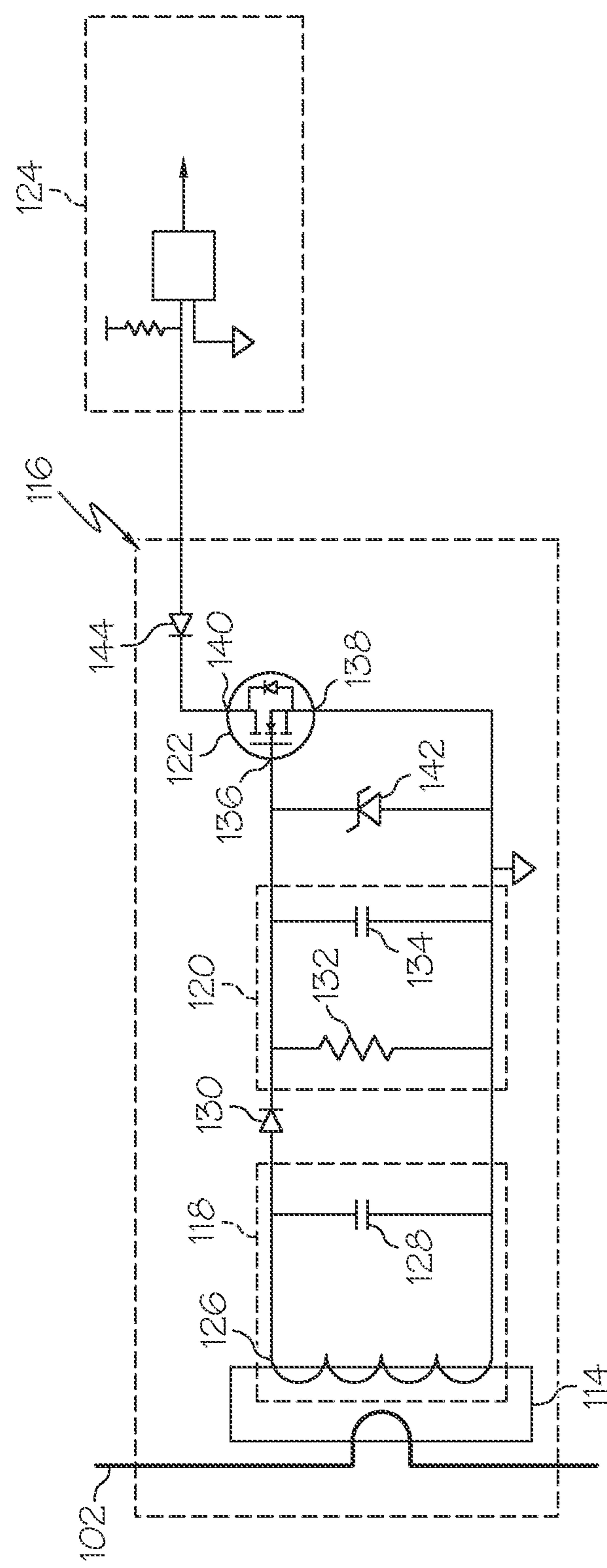


FIG. 3A

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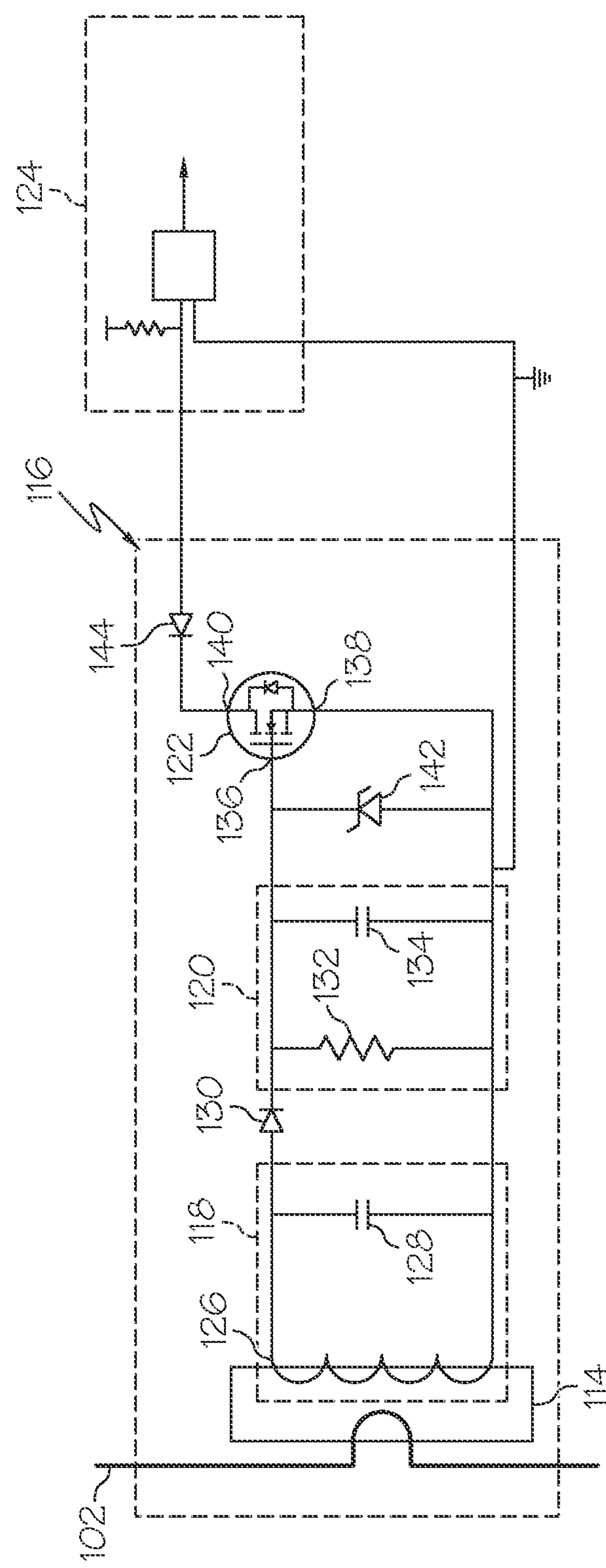


FIG. 3B

