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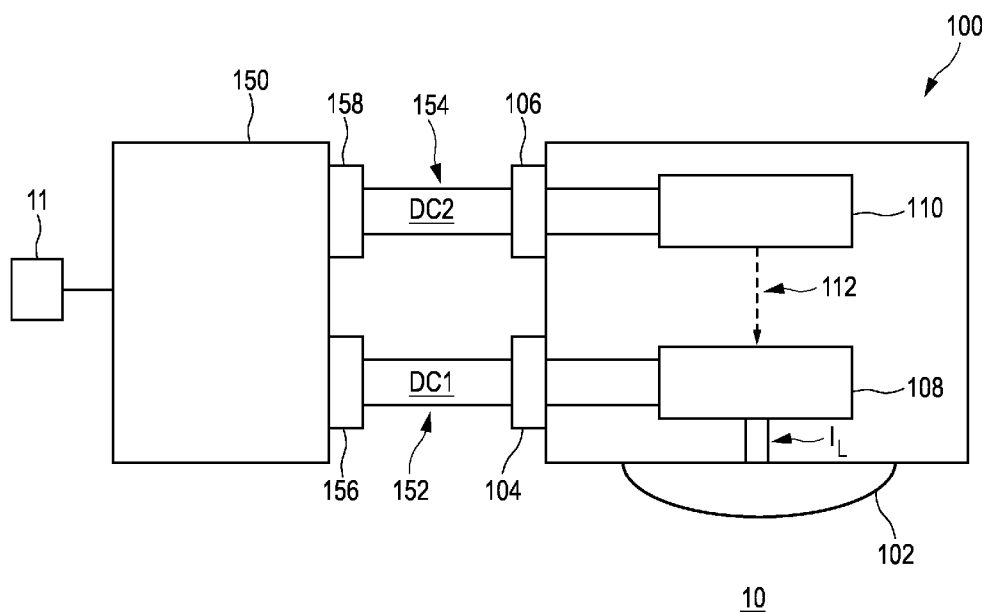


FIG. 2

(57) Abstract: The invention is directed to a DC-powered lighting device (100), comprising a lighting unit (102), a first DC-power input unit (104) for receiving a first DC-power (DC1) via a first wired channel (152), a second DC-power input unit (106) for receiving a second DC-power (DC2) via a second wired channel (154), a lighting driver unit (108) connected to the first DC-power input unit and configured to generate and provide a lighting current (I_L) for operating the lighting unit using the first DC-power; and a communication unit (110) connected to the second DC-power input unit for receiving the second DC-power and configured to establish a wired communication channel with the power sourcing equipment for providing or receiving communication signals, thereby enabling operation of the communication unit independently of an operational state of the lighting unit.

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DC-powered lighting device and method for controlling operation thereof

FIELD OF THE INVENTION

The invention is directed to a DC-powered lighting device, to a lighting arrangement comprising a DC-powered lighting device, to a method for controlling operation of a DC-powered lighting device and to a computer program.

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BACKGROUND OF THE INVENTION

US 2018/0375673 describes a power receiving device, such as a lighting device, configured to be provided with power, in particular DC-power, by a power providing device. The power receiving device comprises a power receiving unit configured to receive power from the power providing device at a first voltage and at a second voltage, and a power reception control unit configured to control the power receiving device to operate in a first mode and in a second mode, wherein the power reception control unit is configured to control the power receiving device to operate in the first mode upon receiving power at the first voltage and is further configured to control the power receiving device to switch from operating in the first mode to operating in the second mode upon receiving power at the second voltage after receiving power at the first voltage. In an embodiment, a switching to stand-by mode, i.e. a switching from providing power at the first voltage to providing power at the second voltage is automatically initiated when the supply current taken by the power receiving device falls below a predefined/programmable threshold value.

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A DC-powered luminaire is likely to be either powered down or in a stand-by mode during quiescent periods of time. Any additional functions or capabilities of the DC-powered luminaire other than illuminating are therefore only available when the DC-powered luminaire is powered.

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SUMMARY OF THE INVENTION

It would be beneficial to ensure operation of an additional function of the DC-powered device irrespectively of the operational state of the lighting function.

According to a first aspect of the invention, a DC-powered lighting device is disclosed. The DC-powered lighting device comprises a lighting unit for providing light for

illuminating a space. The DC-powered lighting device comprises a first DC-power input unit for receiving a first DC-power from a DC-power sourcing equipment via a first wired channel and a second DC-power input unit for receiving a second DC-power from the DC-power sourcing equipment via a second wired channel. A lighting driver unit is connected to the first DC-power input unit and configured to generate and provide a lighting current for operating the lighting unit using the first DC-power. Further, a communication unit is connected to the second DC-power input unit for receiving the second DC-power and configured to establish a wired communication channel with the power sourcing equipment for providing or receiving communication signals, in accordance with a suitable communication protocol.

The provision of two separate DC-powers by the same DC-power sourcing equipment, via a respective wired channel, each one of the DC-power for powering a respective one of the lighting driving unit, which controls the provision of the lighting current for operating the lighting unit, and the communication unit, which establishes data communication (i.e., provides communication signals to, and/or receives communication signals from), enables the operation of the communication unit irrespectively of the current operation state of the lighting unit, i.e. even if the lighting unit is not powered or powered in a stand-by mode.

In the following, embodiment of the DC-powered lighting device will be described.

Power over Ethernet (PoE) is a technology that allows provision of electric power over twisted-pair Ethernet cables to so called powered devices (PD), such as wireless access points, IP cameras, VoIP phones, lighting devices, etc., in addition to the data that the Ethernet cable usually carries. It enables one Ethernet cable to provide both data connection and electric power to PDs instead of having a separate cable for each. An embodiment of the DC-powered lighting device is advantageously used in the frame of a power over Ethernet (PoE) based system such as, for instance, a PoE based digital ceiling, where network cabling, such as CAT 5, CAT 6, CAT 7 or CAT 8 cables comprising a plurality of twisted pairs are used for providing power to the devices of the system, which typically include sensors, switches and lighting devices and which may also include other units such as wireless communication units. PoE standard has currently undergone its third revision and now supports up to 75W with flexible power budgeting and standby mechanism.

Thus, preferably, the communication unit is further configured to provide control instructions for operating the lighting driver unit. The control instructions can be

provided by the power sourcing equipment and forwarded to the lighting driver unit via the communication unit, and/or can be generated by the communication unit acting as controller unit.

Preferably, the lighting driver unit is configured to provide the lighting current
5 in dependence on the control instructions provided by the communication unit.

In an embodiment, the first DC-power input and the second DC-power input are integrated in a common connection socket, in particular a socket for an Ethernet cable, where a first set of connectors for a first pair of twisted pair of the Ethernet cable forms the first DC-power input and a second set of connectors for a second pair of twisted pair of the
10 Ethernet cable forms the second DC-power input. Preferably, the DC-powered lighting device of this embodiment is a PoE-capable device.

In another embodiment, the communication unit comprises a DC-power output unit for providing operation DC-power to an external (i.e., not belonging to the DC-powered lighting device) DC-powered device. In particular, the external DC-powered device is a
15 wireless communication unit or wireless access point. The wireless communication unit is configured to provide and/or receive radiofrequency signals in accordance with a predetermined wireless communication protocol, such as, but not limited to, WiFi, Zigbee, Bluetooth, BLE, Thread, LTE, 5G, LiFi, Matter, etc. The wireless communication unit can be advantageously used to provide status data indicative of the operational state of the DC-
20 powered device, to receive status data indicative of the operational state of other devices, such as sensors, switches, etc., or to receive/provide operational instructions to other devices.

The wireless communication unit can be connected to the DC-power output unit via a twisted pair wiring or any other wired connection. In a preferred embodiment, the DC-powered lighting device of the first aspect of the invention comprises a control-and-
25 communication unit connected to the second DC-power input, wherein the control-and-communication unit includes the controller unit and a DC-powered wireless communication unit.

Preferably, according to an embodiment of the DC-powered lighting device of the present invention, an isolation switch is provided. The isolation switch is configured to
30 control reception of the first DC-power. The isolation switch can therefore be also configured to control the provision of the lighting current to the lighting unit. Control in this case means to allow or prevent the provision of the lighting current for operating the lighting unit. Typically, when the lighting unit is on, the parameters of the lighting unit (e.g., light intensity, light spectrum, color temperature, dynamic effects, etc.) can be controlled via the

controller unit. The control instructions can be received via the wired connection with the power sourcing equipment, in particular via the first wired channel. Additionally, or alternatively, in an embodiment comprising a wireless communication unit, control instructions can be received wirelessly via the wireless communication unit.

5 In an embodiment, the DC-powered lighting device of the first aspect of the invention further comprises a power negotiation unit. The power negotiation unit is connected to the first DC-power input unit and to the second DC-power input unit and is configured to negotiate a required DC-power amount with the external DC-power sourcing equipment in accordance with a predetermined power-negotiation protocol. Preferably, the
10 power sourcing equipment is configured to provide DC-power via the first wired channel and/or the second wired channel only after it has detected that the connected device is a DC-powered device. Further, an amount of DC-power is also negotiated based on the nature of the connected DC-powered device and its minimum power requirements. In the present embodiment, this is achieved by means of a power negotiation unit. In an embodiment, the
15 power negotiation unit comprises a first power negotiation unit for negotiating the first DC-power to be received via the first wired channel and a second power negotiation unit for negotiating the second DC-power to be received via the second wired channel.

Typically, a relatively low power load will be supplied via the second DC-power input, for operating the controller unit, and, if applicable, the wireless communication
20 unit. A relatively low power load compared to that required for operating the lighting unit, which is provided via the first DC power input. Thus, in an embodiment, the power negotiation unit comprises a power balancing unit that is configured to control provision of at least a part of the first DC-power to the controller unit and/or at least a part of the second DC-power amount to the lighting driver unit. Thus, the controller unit is further configured to
25 provide the control instructions using the first DC-power amount and/or the second DC-power amount. Additionally or alternatively, the lighting driver unit is configured to provide the lighting current using the first DC-power amount and/or the second DC-power amount. The power balancing unit allows to balance the current as drawn from the first DC-power input and from the second DC-power input. This enables a reduction of power losses in the
30 connection cable (e.g., Ethernet cable) and best use of the electronics, since both the first wired channel and the second wired channel can provide a similar amount of DC-power. In detail, this means that a fraction of the first DC-power used for light generation can be drawn from the second wired channel. Typically the lighting unit is supplied with a higher DC-power than the controller unit or the control-and-communication unit. However, in some

cases, the controller unit, especially the control-and-communication unit may need peak DC-power values higher than what a signal wired channel can deliver and then the necessary DC-power can be drawn from the first DC-power input via the power balancing unit. High DC-power may be required for example in the case of wireless communication unit configured as a 5G based access point.

According to a second aspect of the present invention, a lighting arrangement is described. The lighting arrangement comprises at least a DC-powered lighting device according to any of the preceding claims. The one or more DC-powered devices are connected to a power sourcing equipment. The power sourcing equipment is configured to be connected to a mains power supply and comprises a DC-power output interface including a first DC-power output unit for providing the first DC-power via the first wired channel, and a second DC-power output unit for providing the second DC-power via the second wireless channel.

The lighting arrangement of the second aspect of the invention thus shares the advantages of the DC-powered device of the first aspect of the invention or of any of its embodiments.

In the following, embodiment of the lighting arrangement of the second aspect will be described.

The power sourcing equipment can be a PoE network switch, also referred to an endpoint or endspan. Since the PoE network switch itself can provide DC-power to the DC-powered devices connected thereto, there is no need for an additional power source between the PoE switch and the connected DC-powered devices, also referred to as PoE edge device.

In cases where a non-PoE enabled network switch is to be used with a PoE device, a power source that injects DC-power into the wired channels is required. This device, usually referred to as PoE midspan or PoE injector, is placed between the non-PoE network switch and the DC-powered device.

In an embodiment, the first wired channel and/or the second wired channel comprise a respective twisted pair wiring. In particular the first wired channel and the second wired channel are part of a common cable, such as an Ethernet cable, for example a CAT 5, CAT 6, CAT 7 or CAT 8 cable.

In another embodiment, the power sourcing equipment comprises a DC-powered lighting device identification unit that is configured to identify a connection of a DC-powered lighting device to the DC-power output interface and to provide DC-power

upon determining that a connected device is a DC-powered lighting device. The DC-powered lighting device identification unit is advantageously configured to cooperate with a power negotiation unit of the DC-powered lighting device to negotiate the amount of DC-power to be provided via each of the first wired channel and the second wired channel.

5 In yet another embodiment, the power sourcing equipment is further configured to provide, via the first wired channel, operation instructions to the controller unit for operating the lighting unit.

A third aspect of the present invention is formed by a method for controlling operation of a DC-powered lighting device. The method comprises:

10 - receiving a first DC-power from a DC-power sourcing equipment via a first wired channel;

- receiving a second DC-power from the DC-power sourcing equipment via a second wired channel;

15 - generating and providing a lighting current for operating the lighting unit using the first DC-power; and

- operating a communication unit, in particular generating and providing control instructions for operating a lighting driver unit, using the second DC-power;

The lighting current is then provided in dependence on the control instructions received.

20 The method of the third aspect thus shared the advantages of the DC-powered device of the first aspect or of any of its embodiments.

A further aspect of the invention is formed by a computer program comprising instructions which, when executed by a DC-powered lighting device, cause the DC-powered lighting device to carry out the method of the third aspect.

25 It shall be understood that the DC-powered lighting device of claim 1, the lighting arrangement of claim 9, the method for controlling operation of a DC-powered lighting device of claim 14, and the computer program of claim 15, have similar and/or identical preferred embodiments, in particular, as defined in the dependent claims.

30 It shall be understood that a preferred embodiment of the present invention can also be any combination of the dependent claims or above embodiments with the respective independent claim.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following drawings:

Fig. 1 shows a schematic block diagram of a lighting arrangement, in particular a PoE based lighting arrangement in accordance with one embodiment of the invention;

Fig. 2 shows a schematic block diagram of an exemplarily DC-powered lighting device in accordance with an embodiment of the invention;

Fig. 3 shows a schematic block diagram of an exemplarily DC-powered lighting device in accordance with another embodiment of the invention;

Fig. 4 shows a schematic block diagram of an exemplarily DC-powered lighting device in accordance with another embodiment of the invention;

Fig. 5 shows an electric circuit of an exemplarily DC-powered lighting device in accordance with yet another embodiment of the invention;

Fig. 6 shows a schematic block diagram of another exemplarily DC-powered lighting device in accordance with yet another embodiment of the invention;

Fig. 7 shows a flow diagram of an exemplary method in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Fig. 1 shows a schematic block diagram of a lighting arrangement 1000, in particular a PoE based lighting arrangement in accordance with one embodiment of the invention. The lighting arrangement 1000 shown in Fig. 1 can be for instance the lighting part of a digital ceiling system in the frame of a building management system. A power sourcing equipment 150, in this case a PoE compatible power sourcing equipment, also known as PoE switch is connected to AC mains supply 11 for receiving the operational power that is required for its operation. A data connection 12 is available for providing and receiving data signals (e.g., indicative of operation instructions, status information, etc.). Three DC-powered lighting devices 100.1, 100.2 and 100.3 are connected to the power sourcing equipment 150 via a separate dedicated PoE connection, in particular via respective Ethernet cables (e.g. CAT 5, CAT 6, CAT 7 or CAT 8 cables) 13.1, 13.2, 13.3. The DC-powered lighting devices 100.1, 100.2 and 100.3 comprise preferably an LED based lighting unit mounted in a luminaire 14 and driven via a PoE driver 15 acting as a PoE powered device that is configured to request DC power from the power sourcing equipment 150. For the sake of simplicity, these features are only shown for DC-powered lighting device 100.3.

However, they are also comprised by the remaining DC-powered lighting devices 100.1 and 100.2. The PoE driver 15 is also configured to provide the driving current for the LED's in the luminaire. Additionally, the PoE driver is also configured to receive and/or provide communication signals via the Ethernet connection to the PoE switch 150, for instance for controlling or monitoring functions, in particular controlling functions associated to the lighting unit.

Fig. 2 shows a schematic block diagram of an exemplarily DC-powered lighting device 100 in accordance with an embodiment of the invention that is suitable for use in a lighting arrangement, such as lighting arrangement 1000 of Fig. 1. The DC-powered lighting device 100, comprises a lighting unit 102 for providing light for illuminating a space 10. The DC-powered lighting device comprises a first DC-power input unit 104 for receiving a first DC-power DC1 from a DC-power sourcing equipment 150 via a first wired channel 152 and a second DC-power input unit 106 for receiving a second DC-power DC2 from the DC-power sourcing equipment 150 via a second wired channel 154. The DC-powered lighting device 100 comprises a lighting driver unit 108 that is connected to the first DC-power input unit and configured to generate and provide a lighting current I_L for operating the lighting unit using the first DC-power. Further, the DC-powered lighting device comprises a communication unit 110 that is connected to the second DC-power input unit for receiving the second DC-power and configured to establish a wired communication channel with the power sourcing equipment for providing or receiving communication signals. The combination of the communication unit 110 and the lighting driver unit 108 may form a PoE driver 15, as described with reference to Fig. 1. The power sourcing equipment 150 is configured to be connected to a mains power supply 11 and comprises a first DC-power output unit 156 for providing the first DC-power DC1 via the first wired channel 152, and a second DC-power output unit 158 for providing the second DC-power DC2 via the second wired channel 154.

The communication unit 110 can be advantageously configured to provide control instructions 112 for operating the lighting driver unit. The control instructions can be indicative of operation parameter of the lighting unit, such as, light intensity, spectrum, colour temperature, a dynamic effect, etc. The control instructions may be received from the power sourcing equipment 150 via the second wired connection channel 154 or can be generated by the communication unit, for instance based on status information or specific input data, for example from a presence sensor or a light sensor, or a predetermined operation schedule.

Fig. 3 shows a schematic block diagram of an exemplarily DC-powered lighting device 100b in accordance with another embodiment of the invention. For the sake of clarity, those technical features of the device 100b that have an identical or similar function as those of the DC-powered lighting device 100 of Fig. 2 will be referred to using the same reference numbers. In particular, in the DC-powered lighting device 100b of Fig. 3 the first DC-power input and the second DC-power input are integrated in a common connection socket, for instance a RJ45 socket for an Ethernet cable. Correspondingly, the first DC-power output 156 and the second DC-power output 158 of the power sourcing equipment 150b are integrated in a common socket 155.

Optionally, the DC-powered device 100b (or 100) may include a DC-power output unit 114 for providing operation DC-power DC3 to an external DC-powered device, such as a wireless communication unit 116. Other suitable DC-powered devices that can be connected to the DC-power output unit 114 include, but are not limited to a sensing device, a switch, another lighting device such as an emergency lighting, etc. Preferably, the DC-powered device 116 is connected to the DC-power output unit via a twisted pair wiring 115 for provision of the operation DC-power, for instance in accordance with a PoE protocol. In a further developed embodiment the DC-powered lighting device may be able to power a wireless communication unit like a Wi-Fi or a LiFi access point, preferably with a connection by means of twisted pair wiring 115. In order to keep the connectivity function available even when the lighting unit is inactive (meaning the lighting driver unit is switched off and channel B, is disconnected), the wireless communication unit is connected to channel A. As discussed above channel A is constantly connected, connecting the power sourcing equipment to the communication unit.

Fig. 4 shows a schematic block diagram of another exemplarily DC-powered lighting device 100c in accordance with another embodiment of the invention. For the sake of clarity, those technical features of the device 100c that have an identical or similar function as those of the DC-powered lighting device 100 of Fig. 2 and of DC-powered lighting device 100b of Fig. 3 will be referred to using the same reference numbers. In particular, in the DC-powered device 100c comprises a controller unit 118 that includes the communication unit 110 and a wireless communication unit 116. The controller 118 unit is connected to the second DC power input unit for reception of the second DC-power. In alternative DC-powered lighting devices, the controller unit alternatively or additionally comprises other functional units, such as a sensor unit (presence sensor, temperature sensor, light sensor, a humidity sensor, etc.). The data gathered by the sensor unit can be used by the controller unit

to control operation of the lighting unit. Additionally, or alternatively, the controller unit can provide communication signals indicative of the gathered data or of the operational state of the lighting unit to the power sourcing equipment 150b, via the second wired channel 154.

Fig. 5 shows an electric circuit of an exemplarily DC-powered lighting device 100d in accordance with yet another embodiment of the invention. Here again, those features having an identical or similar function to those previously described will be referred to using the same reference numbers. The DC-powered lighting device 100d of Fig. 5 comprises a power interface PI that includes the first DC-power input unit 104 and the second DC-power input unit 106, for connecting a first wired channel 152 and a second wired channel 154 respectively, for instance a respective wired pair of an Ethernet cable. The first and the second DC-power input unit comprise a respective diode bridge rectifier 140. The DC-powered lighting device 100d further comprises a power negotiation unit 120 that is connected to the first DC-power input unit 104 and to the second DC-power input unit 106 and configured to negotiate a required DC-power amount with the external DC-power sourcing equipment in accordance with a predetermined power-negotiation protocol, such as those implemented in IEEE 802.3 standards (e.g. IEEE802.3af, IEEE802.3at or IEEE802.3bt). The DC-powered lighting device also comprises a respective isolation switch 121.1 and 121.2 to control reception of the first and the second DC-power respectively. Alternatively or additionally, the isolation switch 121.1 controls provision of the lighting current for operating the lighting unit 102.

In this particular example, the DC-powered lighting device is in a dual load-dual signature configuration, wherein each of the loads, namely the lighting driver unit and the communication unit receive DC-power from a respective one of the two wired channels. Thus, and this applies to any of the exemplary DC-powered lighting devices according to the invention, even when the lighting unit is in a stand-by mode and the lighting driver unit is receiving the minimal amount of DC power necessary, the communication unit can still operate at full capacity. DC-Power can be cut for one of the loads without interrupting provision of power to the other load.

In a further developed embodiment the power sourcing equipment is configured to keep track of the negotiated power, in particular for the lighting unit. In such a case no new identification, classification routine (which is typical for PoE) needs to be executed and the power budgeting of the power sourcing equipment will automatically assume the last requested power value in the moment the lighting unit is reconnected. Only when also the communication unit A is disconnected, the requested power memory will be

erased and at new connection of the DC-powered lighting device the DC power will be renegotiated. This is typically the case after system power loss at the mains connection 11 or when PoE connections 13.1, 13.2, 13.3 are changed (see Fig. 1).

The PSE power management functionality can make use of this for a stand-by optimized powering, e.g., the power supply in the PSE may have multiple stages (registers) which are activated dependent on the drawn power of all connected PoE loads.

Fig. 6 shows a schematic block diagram of another exemplarily DC-powered lighting device 100e in accordance with yet another embodiment of the invention. Also shown in Fig. 6 is the power sourcing equipment (PSE) 150. The PSE comprises a DC-powered lighting device identification unit 160 that is configured to identify a connection of a DC-powered lighting device 100e to the DC-power output interface and to provide DC-power upon determining that a connected device is a DC-powered lighting device. The DC-powered lighting device identification unit 160 comprises a first controller 160A for channel A and a second controller 160B for channel B. The DC-powered lighting device 100e comprises a channel A controller 122A and a channel B controller 122B which are configured to receive DC power from the related PSE channels A, 154 and B, 152. The channel A controller 122A and the channel B controller 122B comprise the respective power negotiation unit, and the isolation switches.

Channel A DC-power, DC2, is used to supply the necessary DC power DC2.1 for operation of the communication unit 110 of the PoE electronics 15. In addition, it may also supply the necessary DC power, DC3 to the wireless communication unit 116, or to any other additional DC-powered unit.

Channel B DC-power, DC1, is used to supply the power DC1.1 to the lighting driver unit 108 which is configured to generate and provide the current I_L for driving the lighting unit 102 in the luminaire 14. The lighting driver unit 108 can be controlled by control instructions 112 provided by the communication unit 110.

Optionally, in a further developed embodiment, a power balancing unit can be added which allows to balance the current as drawn through channel A and channel B. This results in minimal power loss in the PoE cabling and best use of all the installed semiconductors. Figure 6 depicts such an embodiment where the power balancing unit 124 ensures that both channels A and B deliver the same power. In detail this means that a fraction of the light generating power DC1.1 is taken from channel A. However, in some cases the additional DC-powered device (such as the wireless communication unit 116) may need peak powers even higher than those that a single channel can deliver. In this case part of

the DC power, DC3 is drawn from channel B. High DC-power use may be required, for instance, for 5G communication units. In an alternative embodiment the dual signature PoE PD interfacing comprising the channel A controller 122A and the channel B controller 122B is bundled in a module. This may even be placed separately from the luminaire electronics and deliver data and stand-by and control power to the communication module 110 as well as lighting power DC1.1 separately to the luminaire electronics and external wireless communication unit 116. In a further developed embodiment easy upgradeability to include communication functionality is guaranteed by a modular approach and a dedicated communication module socket as part of the luminaire 14. Generally, in dual signature PoE arrangements, two pairs of twisted pair form one DC-circuit and the remaining two pairs of twisted pairs of an 8-conductor Ethernet cable form the second DC-circuit.

Fig. 7 shows a flow diagram of an exemplary method 500 in accordance with an embodiment of the invention. The method 500 for controlling operation of a DC-powered lighting device comprises, in a step 502, receiving a first DC-power from a DC-power sourcing equipment via a first wired channel. The method further comprises, in a step 504, receiving a second DC-power from the DC-power sourcing equipment via a second wired channel. The method also comprises, in a step 506, generating and providing a lighting current for operating the lighting unit using the first DC-power, and, in a step 508, operating a communication unit using the second DC-power.

In summary, the invention is directed to a DC-powered lighting device, comprising a lighting unit, a first DC-power input unit for receiving a first DC-power via a first wired channel, a second DC-power input unit for receiving a second DC-power via a second wired channel, a lighting driver unit connected to the first DC-power input unit and configured to generate and provide a lighting current for operating the lighting unit using the first DC-power; and a communication unit connected to the second DC-power input unit for receiving the second DC-power and configured to establish a wired communication channel with the power sourcing equipment for providing or receiving communication signals, thereby enabling operation of the communication unit independently of an operational state of the lighting unit.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality.

A single unit or device may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

5 A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium, supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems.

Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. DC-powered lighting device (100), comprising:
 - a lighting unit (102) for providing light for illuminating a space (10);
 - a first DC-power input unit (104) for receiving a first DC-power (DC1) from a DC-power sourcing equipment (150) via a first wired channel (152);
 - 5 - a second DC-power input unit (106) for receiving a second DC-power (DC2) from the DC-power sourcing equipment (150) via a second wired channel (154);
 - a lighting driver unit (108) connected to the first DC-power input unit and configured to generate and provide a lighting current (I_L) for operating the lighting unit using the first DC-power;
 - 10 - a communication unit (110) connected to the second DC-power input unit for receiving the second DC-power and configured to establish a wired communication channel with the power sourcing equipment for providing or receiving communication signals; and
 - an isolation switch (122) configured to control reception of the first DC-power and/or provision of the lighting current for operating the lighting unit.
- 15 2. The DC-powered lighting device of claim 1, wherein the first DC-power input (104) and the second DC-power input (106) are integrated in a common connection socket (105).
- 20 3. The DC-powered lighting device of claim 1 or 2, wherein the communication unit (110) comprises a DC-power output unit (114) for providing operation DC-power (DC3) to an external DC-powered device (116).
4. The DC-powered lighting device of claim 3, wherein the DC-power output
25 unit (114) is connectable to the external DC-powered device (116) via a twisted pair wiring (115) for provision of the operation DC-power.

5. The DC-powered lighting device of any of the preceding claims, wherein the communication unit is configured as a control unit that is connected to the lighting driver unit and configured to provide control instructions for operating of the lighting driver unit.

6. The DC-powered lighting device of any of the preceding claims, further comprising a power negotiation unit (120) connected to the first DC-power input unit and to the second DC-power input unit and configured to negotiate a required DC-power amount with the external DC-power sourcing equipment in accordance with a predetermined power-negotiation protocol.

7. The DC-powered lighting device of claim 6, wherein the power negotiation unit comprises a power balancing unit that is configured to control provision of at least a part of the first DC-power to the communication unit and/or at least a part of the second DC-power amount to the lighting driver unit,

wherein the communication unit is further configured to operate using the first DC-power amount and/or the second DC-power amount; and/or

wherein the lighting driver unit is further configured to provide the lighting current using the first DC-power amount and/or the second DC-power amount.

8. Lighting arrangement, comprising:

- at least a DC-powered lighting device according to any of the preceding claims;

- a power sourcing equipment configured to be connected to a mains power supply and comprising a first DC-power output unit (156) for providing the first DC-power via the first wired channel, and a second DC-power output unit (158) for providing the second DC-power via the second wired channel.

9. The lighting arrangement of claim 8, wherein the first wired channel and/or the second wired channel comprise a respective twisted pair wiring.

10. The lighting arrangement of claim 9, wherein the first wired channel and the second wired channel are included in a common cable.

11. The lighting arrangement of any of the preceding claims, wherein the power sourcing equipment comprises a DC-powered lighting device identification unit that is configured to identify a connection of a DC-powered lighting device to the DC-power output interface and to provide DC-power upon determining that a connected device is a DC-powered lighting device.

12. The lighting arrangement of any of the preceding claims 9 to 10, wherein the power sourcing equipment is further configured to provide, via the first wired channel, operation instructions (112) to the communication unit (110) of the DC-powered lighting device (100) for operating the lighting unit (102).

13. Method (500) for controlling operation of a DC-powered lighting device, the method comprising;

- receiving (502) a first DC-power from a DC-power sourcing equipment via a first wired channel;

- receiving (504) a second DC-power from the DC-power sourcing equipment via a second wired channel;

- generating and providing (506) a lighting current for operating the lighting unit using the first DC-power;

- operating (508) a communication unit of the DC-powered lighting device using the second DC-power; and

- using an isolation switch (122) configured to control reception of the first DC-power and/or provision of the lighting current for operating the lighting unit.

14. Computer program comprising instructions which, when executed by a DC-powered lighting device, cause the DC-powered lighting device to carry out the method of claim 13.

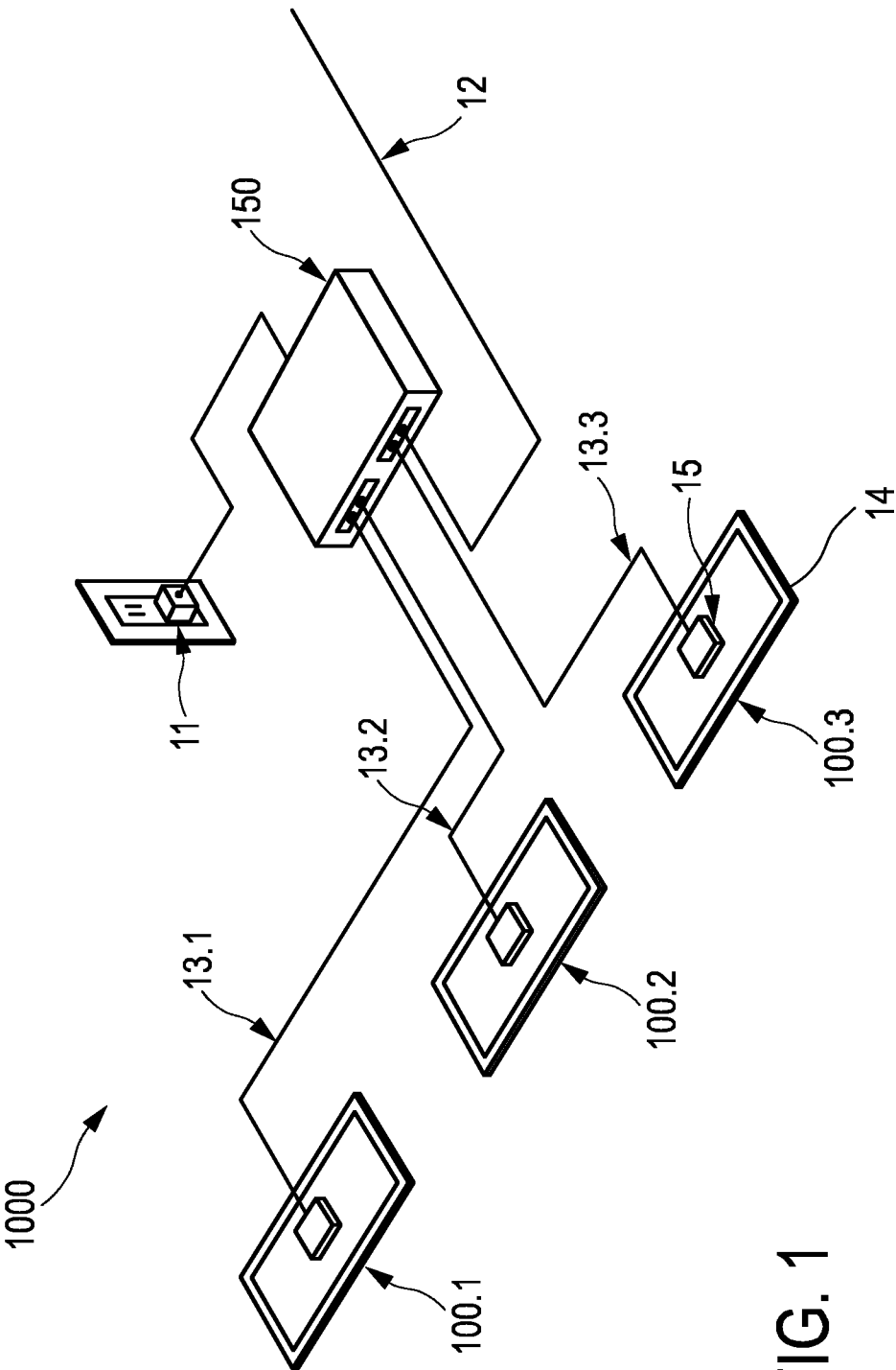


FIG. 1

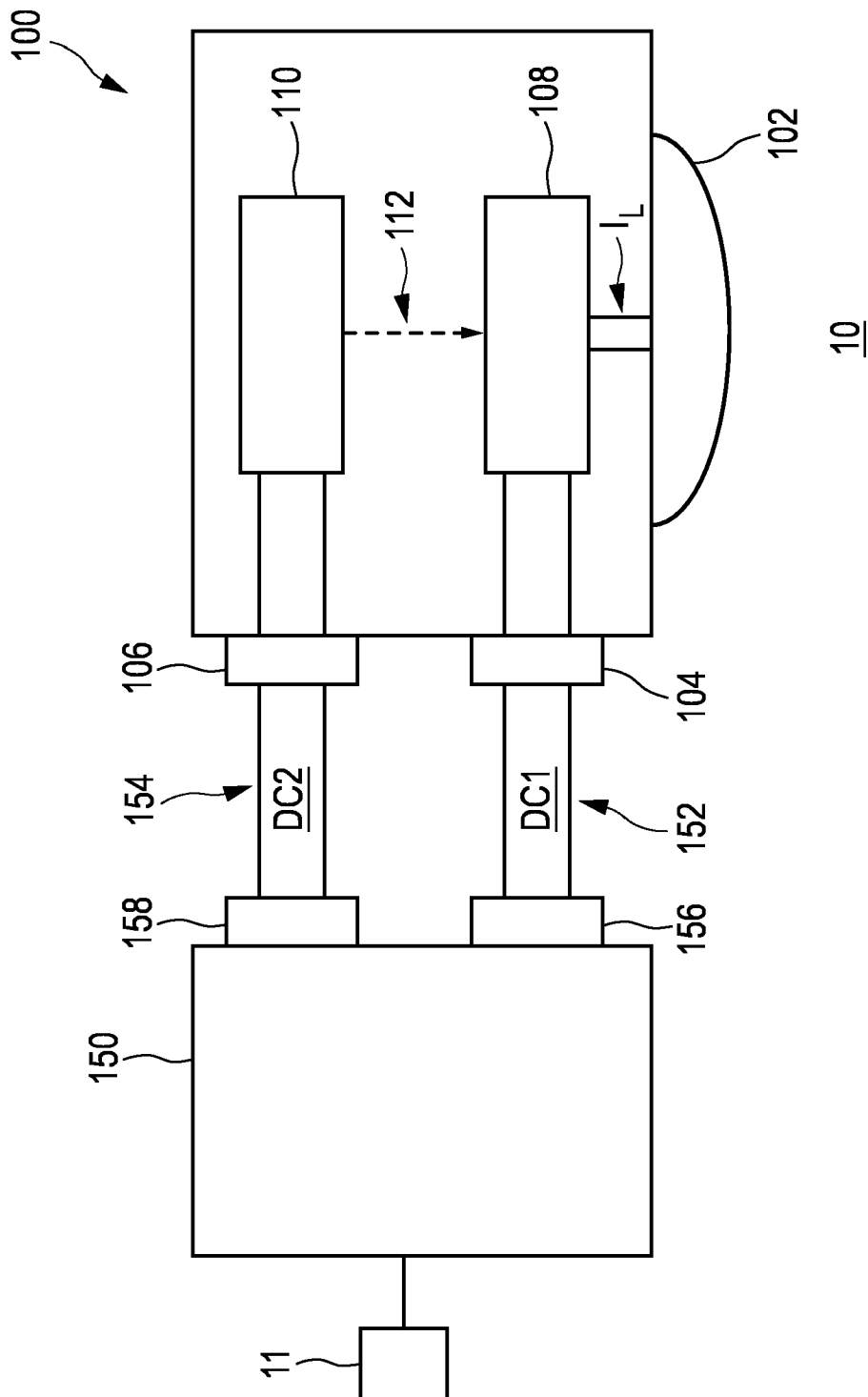


FIG. 2

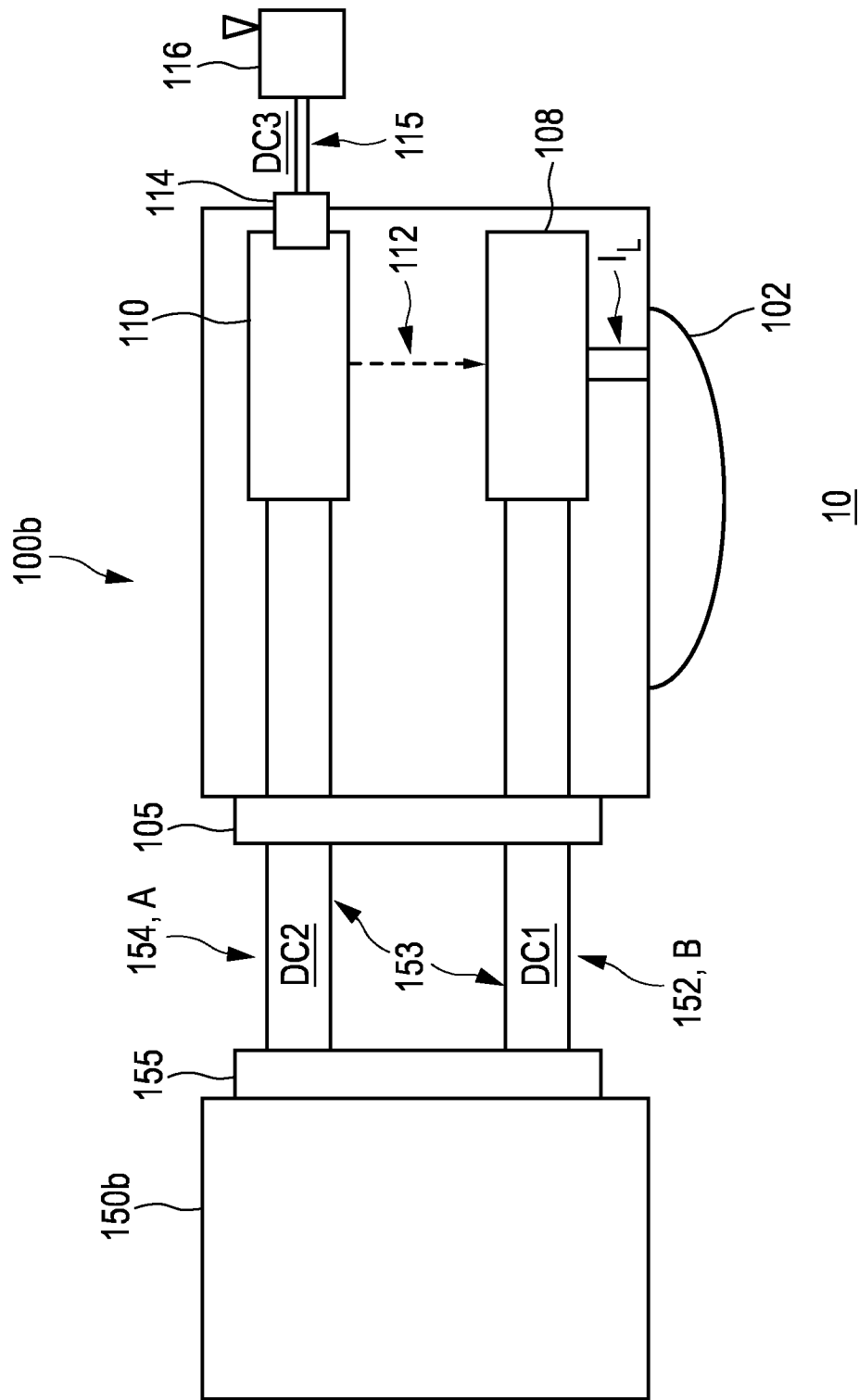


FIG. 3

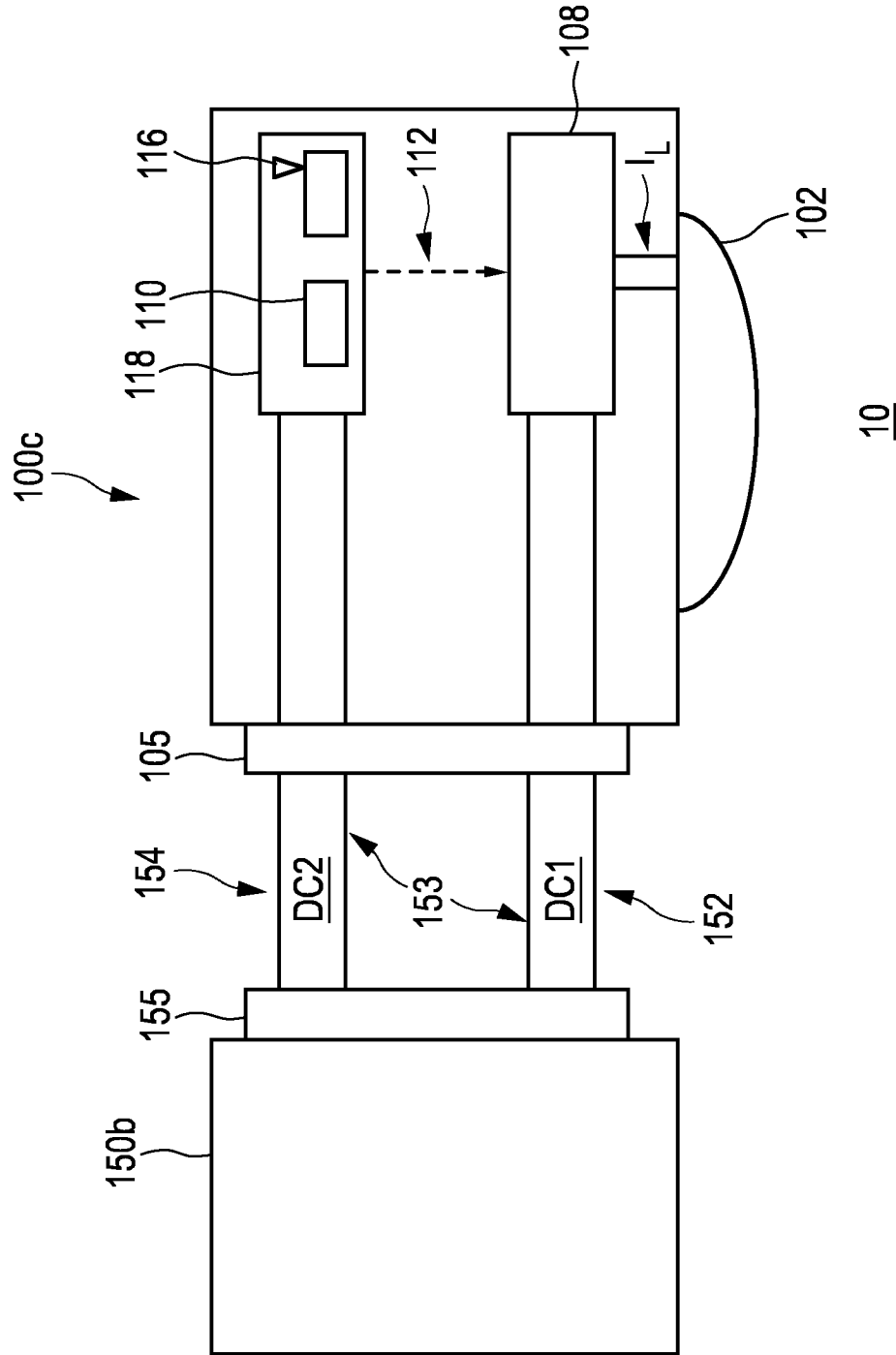


FIG. 4

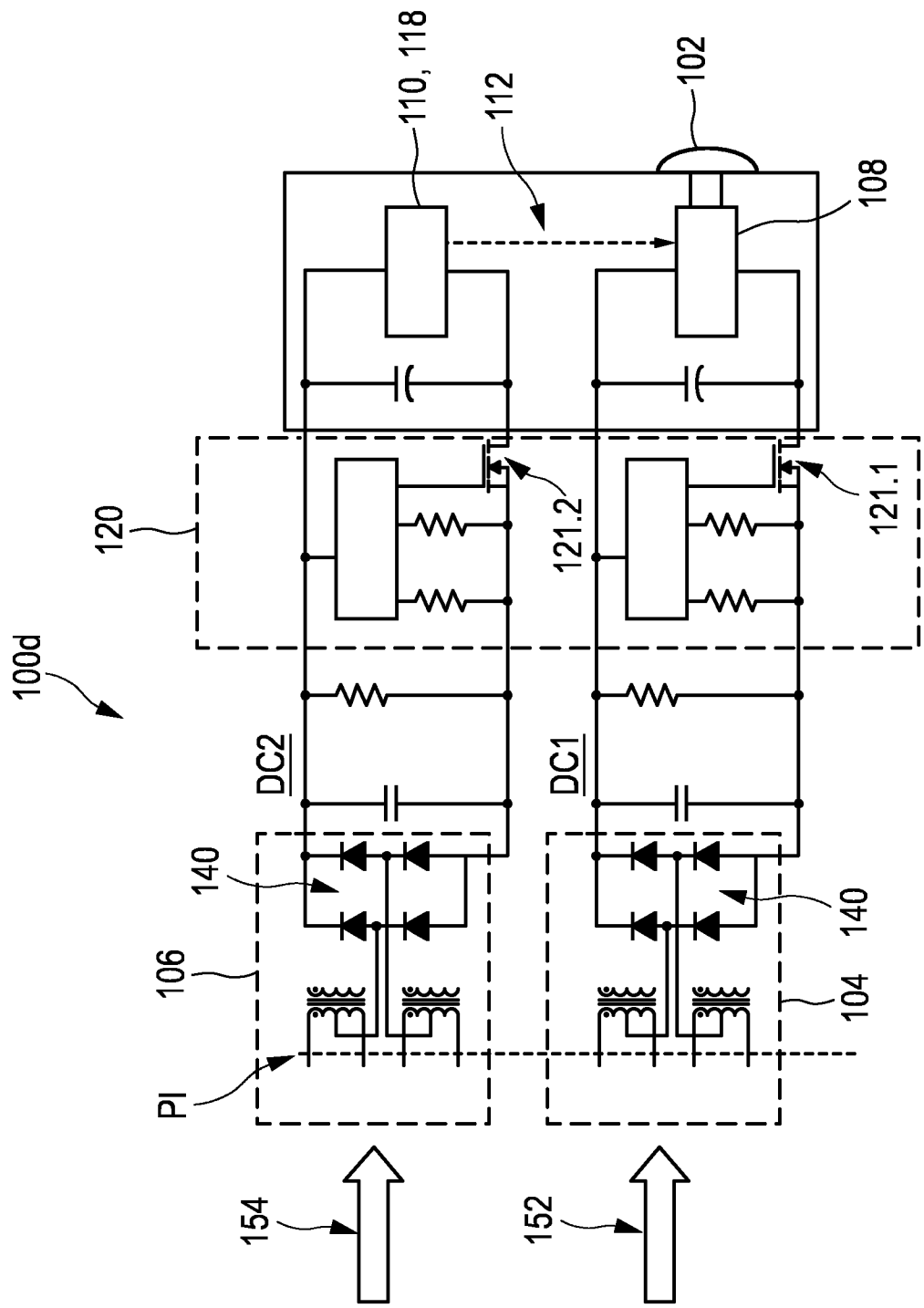
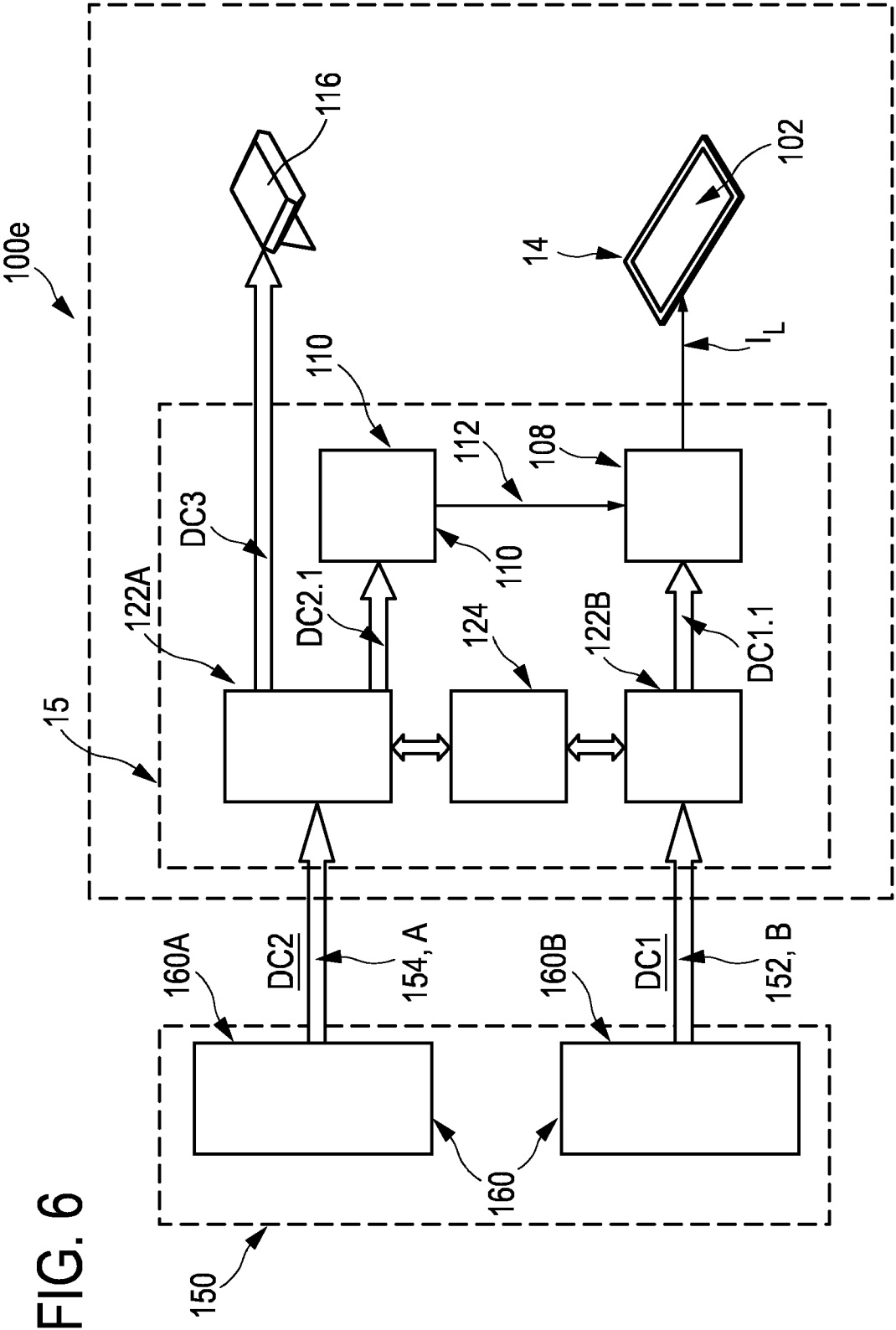


FIG. 5



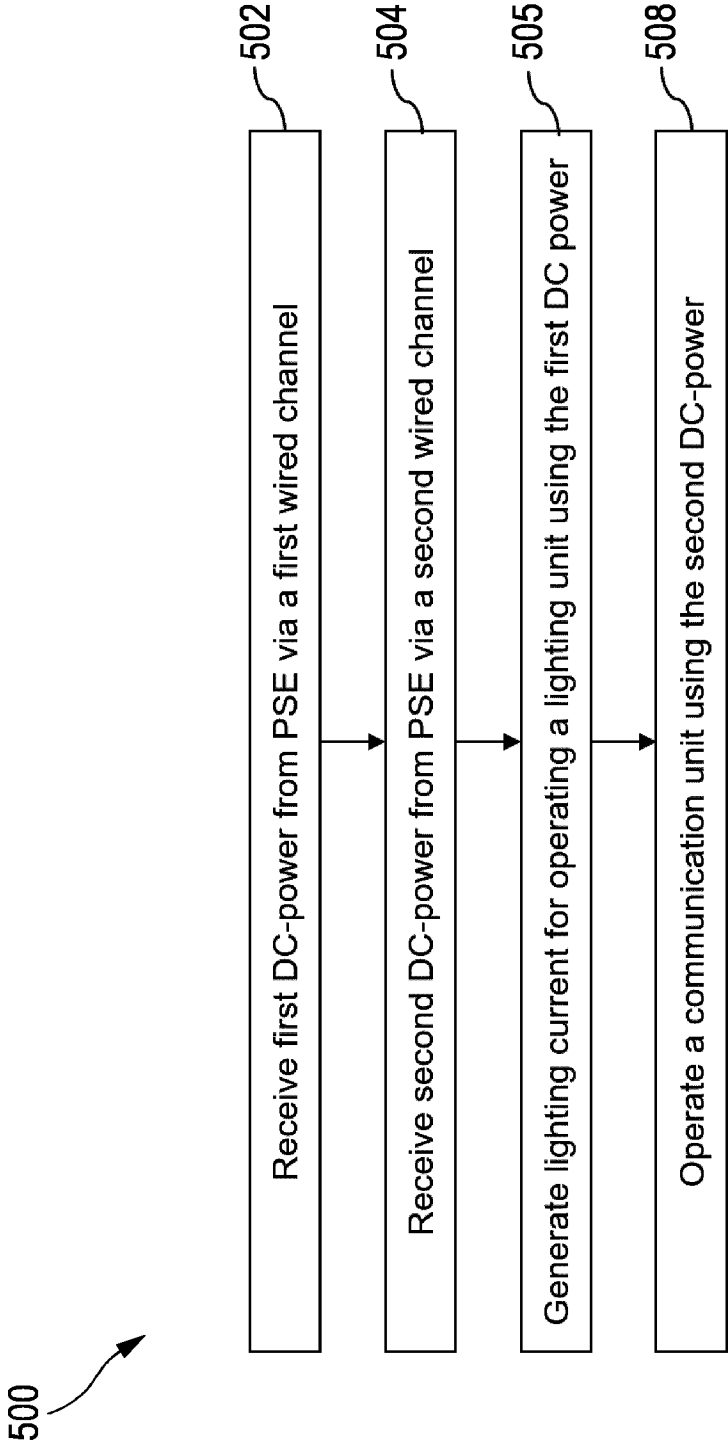


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/065323**A. CLASSIFICATION OF SUBJECT MATTER**INV. H05B47/185 H05B47/18
ADD.

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)

H05B H02J H04L H04Q

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)

EPO-Internal, WPI Data, INSPEC, COMPENDEX, FSTA, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 3 138 181 A1 (IOTA ENG LLC [US]) 8 March 2017 (2017-03-08) page 1, paragraph 2; figures 1-10 page 3, paragraph 8 - page 4, paragraph 15 page 6, paragraph 30 - page 17, paragraph 67 esp. pars. [0031] - [0033]; Fig. 4 -----	1 - 14
Y	US 2015/195883 A1 (HARRIS MICHAEL JAMES [US] ET AL) 9 July 2015 (2015-07-09) page 1, paragraphs 2, 6; figures 1-48 page 2, paragraph 61 - page 33, paragraph 307 esp. pars. [0279] - [0307]; Figs. 41-48 ----- - / - -	1 - 14



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

12 July 2024

Date of mailing of the international search report

22/07/2024

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2024/065323

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2021/281106 A1 (ALLER HARRY [US] ET AL) 9 September 2021 (2021-09-09) page 1, paragraph 10-14; figures 1-6 page 1, paragraph 21 - page 3, paragraph 46 esp. pars. [0024], [0040]-[0042]; Fig. 3 -----	1, 8, 13, 14
Y	WO 2013/107015 A1 (ERICSSON TELEFON AB L M [SE]; CHEN LING [CN]) 25 July 2013 (2013-07-25) page 1, paragraph 1; figures 1-3 page 3, paragraph 11 - page 4, paragraph 14 page 5, paragraph 22 - page 14, paragraph 61 esp. pars. [0006], [00011], [00044]-[00061]; Figs. 3a-3c -----	1-14
Y	US 2018/375673 A1 (WENDT MATTHIAS [DE] ET AL) 27 December 2018 (2018-12-27) cited in the application page 1, paragraph 1; figures 1-12 page 1, paragraph 6 - page 3, paragraph 35 page 3, paragraph 51 - page 6, paragraph 107 page 6, paragraph 113 - page 7, paragraph 114 esp. pars. [0006], [0012]-[0016], [0028], [0029], [0051]-[0057], [0097], [0098], [0114]; Figs. 1, 2, 11 -----	1-14

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/065323

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3138181	A1	08-03-2017	CA 2952671 A1 22-09-2016
			CN 106537721 A 22-03-2017
			CN 108767969 A 06-11-2018
			EP 3138181 A1 08-03-2017
			MX 362789 B 31-01-2019
			US 2016273722 A1 22-09-2016
			US 2017271914 A1 21-09-2017
			US 2018183264 A1 28-06-2018
			US 2019356162 A1 21-11-2019
			WO 2016149549 A1 22-09-2016
US 2015195883	A1	09-07-2015	US 2015195883 A1 09-07-2015
			US 2015264780 A1 17-09-2015
US 2021281106	A1	09-09-2021	NONE
WO 2013107015	A1	25-07-2013	CN 104429020 A 18-03-2015
			EP 2805449 A1 26-11-2014
			US 2015244535 A1 27-08-2015
			WO 2013107015 A1 25-07-2013
US 2018375673	A1	27-12-2018	CN 108064438 A 22-05-2018
			EP 3318004 A1 09-05-2018
			ES 2713754 T3 23-05-2019
			JP 6867960 B2 12-05-2021
			JP 2018530287 A 11-10-2018
			US 2018375673 A1 27-12-2018
			WO 2017001179 A1 05-01-2017