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## Power supply unit

### Abstract

A power supply unit accommodates a main DC/DC converter and an AC charger (a charging circuit, a sub-DC/DC converter) in a housing. The main DC/DC converter and the sub-DC/DC converter are arranged in the same tier of the housing. The charging circuit is arranged in a tier different from that of the main DC/DC converter and the sub-DC/DC converter. The main DC/DC converter and the sub-DC/DC converter arranged in the same tier of the housing are controlled to operate in a mutually exclusive manner.

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## Background/Summary

(1) This nonprovisional application is based on Japanese Patent Application No. 2021-101468 filed on Jun. 18, 2021 with the Japan Patent Office, the entire contents of which are hereby incorporated by reference.

BACKGROUND

Field

(2) The present disclosure relates to a power supply unit.

Description of the Background Art

(3) Japanese Patent Laying-Open No. 2014-230417 discloses a power converter that accommodates electronic components in a housing. In the housing, a pedestal is arranged that has a plurality of through-holes for flowing refrigerant that cools the electronic components. The electronic components are arranged on different surfaces of the pedestal in this power converter, leading to an increased area for effectively cooling the electronic components.

SUMMARY

(4) Electric-powered vehicles, such as battery electric vehicles and plug-in hybrid electric vehicles, are desired to include smaller-sized in-vehicle devices to have a smaller mounting space (save space) for a wider interior space or the like.

(5) Power converters, such as an AC (alternating current) charger that converts AC power supplied from an AC power supply external to the vehicle into DC (direct current) power for charging a traveling battery, a main DC/DC converter that converts the DC power of the traveling battery into a driving voltage of an auxiliary device, and a sub-DC/DC converter that converts the AC power supplied from the AC power supply to the driving voltage of the auxiliary device, may be mounted on the electric-powered vehicle. In one conceivable example, functions of vehicle-mounted devices including such power converters are integrated into a unit to save space more than when the vehicle-mounted devices are arranged individually.

(6) In the integration of the functions into a unit, however, the vehicle-mounted devices are accommodated in the same housing, and accordingly, a problem associated with the heat generated in each vehicle-mounted device may become significant. In particular, in a case where power converters that may generate a larger amount of heat are arranged adjacent to each other, the risk of failure may increase due to thermal interference between the power converters.

(7) The present disclosure has been made to solve the above problem. An object of the present disclosure is to reduce thermal interference between power converters while reducing a size of a power conversion unit in which the functions of the power converters are integrated.

(8) (1) A power conversion unit according to the present disclosure includes a first power converter, a second power converter, a controller that controls the first power converter and the second power converter, and a housing that has a plurality of accommodation spaces defined by a partition wall and accommodates the first power converter, the second power converter, and the controller. The first power converter and the second power converter are arranged in the same accommodation space of the housing. The controller operates the first power converter and the second power converter in a mutually exclusive manner.

(9) With the above configuration, the first power converter and the second power converter arranged in the same accommodation space of the housing are operated in a mutually exclusive manner. In other words, when any one of the first power converter and the second power converter operates, the other is stopped. As a result, the amount of heat generated by the first power converter and the second power converter can be reduced more than when both the first power converter and the second power converter operate. Thermal interference between the power converters can thus be reduced while reducing a size by unitization.

(10) (2) In one embodiment, the partition wall has a refrigerant passage through which refrigerant flows.

(11) With the above configuration, the refrigerant passage of the partition wall reduces heal generation of the first power converter and the second power converter.

(12) (3) In one embodiment, the power supply unit is mounted on a vehicle configured to perform AC charging of charging a main battery mounted on the vehicle with AC power supplied from an AC power supply external to the vehicle. The first power converter converts electric power of the main battery into electric power to be supplied to an auxiliary device mounted on the vehicle. The second power converter converts electric power supplied from the AC power supply into electric power to be supplied to the auxiliary device.

(13) Considering the ease of mounting on the vehicle, it is desirable to reduce an increase in the height of the power supply unit. The first power converter and the second power converter can supply electric power to the auxiliary device by operating at least one of the power converters, and accordingly, can operate in a mutually exclusive manner. An increase in the height of the power supply unit can be reduced arranging, in the same accommodation space, the first power converter and the second power converter that can operate in a mutually exclusive manner.

(14) (4) In one embodiment, the power supply unit further includes a third power converter that converts the AC power into electric power for charging the main battery. The third power converter is arranged in an accommodation space different from that of the first power converter and the second power converter.
(15) The first power converter and the second power converter can be operated simultaneously with the third power converter. For example, when electric power of the main battery is supplied to the auxiliary device of the vehicle in execution of AC charging, the third power converter is operated to charge the main battery, and the first power converter is operated to convert electric power of the main battery, and then, the converted electric power is supplied to the auxiliary device. For example, when AC power is supplied to the auxiliary device of the vehicle in execution of AC charging, the third power converter is operated to charge the main battery, and the second power converter is operated to convert AC power, and then, the converted electric power is supplied to the auxiliary device. Thermal interference between the power converters can be reduced by arranging the third power converter that can be operated simultaneously with the first power converter and the second power converter in the accommodation space different from that of the first power converter and the second power converter.
(16) (5) In one embodiment, the controller controls the third power converter. The second power converter has a power capacity lower than a power capacity of the first power converter. In execution of AC charging, when power consumption of the auxiliary device is smaller than a threshold, the controller operates the third power converter to charge the main battery, operates the second power converter to supply electric power to the auxiliary device, and stops the first power converter.
(17) (6), (7) In one embodiment, the controller controls the third power converter. The second power converter has a power capacity lower than a power capacity of the first power converter. In execution of the AC charging, when power consumption of the auxiliary device is greater than a threshold, the controller operates the third power converter to charge the main battery, operates the first power converter to supply electric power to the auxiliary device, and stops the second power converter.
(18) With the configuration of each of (5) to (7) above, the controller determines which of the first power converter and the second power converter is to be operated and which of these power converters is to be stopped, depending on whether power consumption of the auxiliary device is greater than the threshold. The threshold is determined, for example, based on the power capacity of the second power converter. The power consumption of the second power converter is generally smaller than the power consumption of the first power converter. Considering power conversion efficiency, thus, when the amount of electric power supplied from the second power converter can cover the power consumption of the auxiliary device, operating the second power converter is more desirable than operating the first power converter. When the power consumption of the auxiliary device is smaller than the power capacity of the second power converter, power conversion efficiency can be increased more by operating the second power converter to supply electric power to the auxiliary device than operating the first power converter to supply electric power to the auxiliary device.
(19) (8) In one embodiment, the vehicle is configured to perform DC charging of charging the main battery with DC power supplied from a DC power supply external to the vehicle. The power supply unit further includes a relay for supplying the DC power to the main battery. The relay is accommodated in an accommodation space different from the accommodation space of the first power converter and the second power converter and an accommodation space of a third power converter.
(20) With the above configuration, the relay is accommodated in an accommodation space different from the accommodation spaces of the first to third power converters. Accordingly, thermal interference with the relay by the first to third power converters can be reduced.

(21) The foregoing and other objects, features, aspects and advantages of the present disclosure will become more apparent from the following detailed description of the present disclosure when taken in conjunction with the accompanying drawings.

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## Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a block diagram showing an example configuration of a vehicle according, to an embodiment.
(2) FIG. **2** is a diagram for illustrating control of a power supply unit during traveling of a vehicle.
(3) FIG. **3** is a diagram for illustrating control of the power supply unit during AC charging.
(4) FIG. **4** is a diagram for illustrating control of the power supply unit during AC charging.
(5) FIG. **5** is a diagram for illustrating control of the power supply unit during DC charging.
(6) FIG. **6** is a flowchart showing a procedure of control of the power supply unit.
(7) FIG. **7** shows operation states of a main DC/DC converter, a charging circuit, and a sub-DC/DC converter.
DESCRIPTION OF THE PREFERRED EMBODIMENTS
(8) An embodiment of the present disclosure will be described below in detail with reference to the drawings. The same or corresponding elements in the drawings have the same reference characters allotted in the figures, description of which will not be repeated.
(9) Overall Configuration
(10) FIG. **1** is a block diagram of an example configuration of a vehicle **1** according to the present embodiment. Vehicle **1** according to Embodiment 1 is a battery electric vehicle. It suffices that vehicle **1** can perform external charging of receiving electric power supplied from an external power supply external to vehicle **1** and performing charging a vehicle-mounted main battery, and vehicle **1** is not limited to a battery electric vehicle. Vehicle **1** may be, for example, a plug-in hybrid electric vehicle or a fuel cell electric vehicle.
(11) Vehicle **1** according to the present embodiment is configured to perform AC charging of receiving AC power supplied from an AC power supply external to vehicle **1** and charging the vehicle-mounted main battery and perform DC charging of receiving DC power supplied from a DC power supply external to vehicle **1** and charging the vehicle-mounted main battery.
(12) Vehicle **1** includes a battery pack **10**, a power supply unit **20**, a front power control unit (hereinafter also referred to as “Fr_PCU” **30**), a low-voltage auxiliary device **40**, a high-voltage auxiliary device **50**, an AC inlet **60**, a DC inlet **70**, and a higher-level ECU (Electronic Control Unit) **100**. Although vehicle **1** according to the present embodiment is configured to drive front wheels, when vehicle **1** is configured to drive all wheels, vehicle **1** further includes a rear power control unit (hereinafter also referred to as “Rr_PCU” **31**).
(13) Battery pack **10** is mounted on vehicle **1** as a driving power supply (i.e., power source) of vehicle **1**. Battery pack **10** includes a main battery **11**, system main relays (hereinafter also referred to as “SMRs”) **12**, **13**, and charging relays (hereinafter also referred to as “CHRs”) **14**, **15**.
(14) Main battery **11** is formed of a stack of a plurality of batteries. The battery is, for example, a secondary battery such as a nickel metal hydride battery or a lithium ion battery. The battery may be a battery having a liquid electrolyte between a positive electrode and a negative electrode, or may be a battery having a solid electrolyte (all-solid-state battery). It suffices that main battery **11** is any rechargeable DC power supply, and a large-capacitance capacitor can also be used.
(15) SMRs **12**, **13** are electrically connected between main battery **11** and power lines PL, NL, respectively. SMR **12** has one end electrically connected to a positive terminal of main battery **11** and the other end electrically connected to power line PL. SMR **13** has one end electrically connected to a negative terminal of main battery **11** and the other end electrically connected to

power line NL. SMRs **12**, **13** switch between open/close states, for example, in accordance with a control signal from higher-level ECU **100**.
(16) Power lines PL, NL electrically connect battery pack **10** to Fr_PCU **30**. Power lines PL, NL are partially accommodated in power supply unit **20**. Power lines PL, NL are equipped with antinoise ferrite cores **81**, **82**. When an Rr_PCU **31** is provided, power lines PL, NL are branched into power lines PL**1**, NL**1**, respectively. Power lines PL**1**, NL**1** are electrically connected to Rr_PCU **31**. Power lines PL**1**, NL**1** are equipped with a ferrite core **83**. Each of ferrite cores **81** to **83** captures a magnetic field generated by a high-frequency noise current and converts the captured magnetic field into heat, thereby reducing noise. Ferrite cores **81** to **83** are each accommodated in power supply unit **20**.
(17) Fr_PCU **30** converts DC power supplied from main battery **11** through power lines PL, NL into AC power and supplies the AC power to a motor generator (not shown). The motor generator is an AC rotating electric machine and is, for example, a permanent-magnet-type synchronous motor including a rotor with an embedded permanent magnet. The rotor of the motor generator is mechanically connected to the front wheels that are driving wheels via a power transmission gear, which are not shown. Fr_PCU **30** includes, for example, an inverter for driving the motor generator and a converter that boosts a DC voltage supplied to the inverter to be not less than an output voltage of main battery **11**.
(18) When vehicle **1** further includes Rr_PCU **31**, Rr_PCU **31** supplies AC power to a motor generator (not shown) with a rotor mechanically connected to the rear wheels via a power transmission gear.
(19) CHRs **14**, **15** are electrically connected between main battery **11** and power lines APL**1**, ANL**1**, respectively. CHR **14** has one end electrically connected to the positive terminal of main battery **11** and the other end electrically connected to power line APL**1**. CHR **15** has one end electrically connected to the negative terminal of main battery **11** and the other end electrically connected to power line ANL**1**. CHRs **14**, **15** switch between open/close states, for example, in accordance with a control signal from higher-level ECU **100**.
(20) Power lines APL**1**, ANL**1** electrically connect CHRs **14**, **15** to an AC charger **22** (not shown) included in power supply unit **20**. When vehicle **1** further includes a solar charger **90**, solar charger **90** is electrically connected to power lines APL**1**, ANL**1**. Solar charger **90** converts electric power generated by a vehicle-mounted solar panel (not shown) into charging power of main battery **11** and supplies the charging power to power lines APL**1**, ANL**1**. When CHRs **14**, **15** are closed, main battery **11** is charged with the electric power from solar charger **90**.
(21) Power supply unit **20** accommodates a plurality of vehicle-mounted devices in a housing and is unitized. Specifically, power supply unit **20** includes a main DC/DC converter **21**, AC charger **22**, a DC relay **25**, a charging integration ECU **26**, and a housing **28**. Housing **28** has a plurality of tiers and accommodates main DC/DC converter **21**, AC charger **22**, DC relay **25**, and charging integration ECU **26**. Fused connectors **87** to **89** are provided on a lateral surface of housing **28**. The arrangement of the vehicle-mounted devices in housing **28** will be described below.
(22) Main DC/DC converter **21** is electrically connected between power lines PL, NL and power line EL. Main DC/DC converter **21** is electrically connected to power lines PL, NL via a fuse **86**. Main DC/DC converter **21** performs voltage conversion of electric power supplied from main battery **11** to power lines PL, NL and supplies the resultant electric power to power line EL. Main DC/DC converter **21** has a power capacity (the capacity to supply a current to power line EL) higher than the power capacity of a sub-DC/DC converter **24**, which will be described below. Main DC/DC converter **21** corresponds to an example of the “first power converter” according to the present disclosure.
(23) Power line EL is electrically connected with low-voltage auxiliary device **40** and an auxiliary battery (not shown). Low-voltage auxiliary device **40** is a device that operates with electric power supplied to power line EL. Low-voltage auxiliary device **40** includes, for example, various ECUs, a

lighting device, an audio device, a navigation device, a power steering device, and the like.

(24) Power lines PL, NL are electrically connected with high-voltage auxiliary device **50** via a connector provided on a lateral surface of housing **28** of power supply unit **20**. High-voltage auxiliary device **50** includes a water heater **51** and an air conditioner **52**.

(25) Water heater **51** is electrically connected to connector **87**. Connector **87** is electrically connected to power lines PL, NL in housing **28** of power supply unit **20**. Water heater **51** is a heater for heating the vehicle interior. Water heater **51** is formed of, for example, a PTC (Positive Temperature Coefficient) heater. Water heater **51** has, for example, a pipe and heats the water circulating inside the pipe to indirectly heat the air.

(26) Air conditioner **52** is electrically connected to connector **88**. Connector **88** is electrically connected to power lines PL, NL in housing **28** of power supply unit **20**. Air conditioner **52** includes a compressor and operates the compressor in accordance with a control signal from higher-level ECU **100** to perform air conditioning of the vehicle interior.

(27) High-voltage auxiliary device **50** may further include an AC-100-V inverter **53** that supplies electric power to an in-vehicle outlet (not shown) provided inside vehicle **1**. AC-100-V inverter **53** is electrically connected to connector **89**. Connector **89** is electrically connected to power lines PL, NL in housing **28** of power supply unit **20**. AC-100-V inverter **53** converts electric power of main battery **11** supplied to power lines PL, NL into electric power (e.g., electric power of AC 100 V) to be supplied to the in-vehicle outlet and outputs the converted electric power to the in-vehicle outlet.

(28) AC charger **22** is electrically connected to battery pack **10** by power lines APL**1**, ANL**1**. AC charger **22** is also electrically connected to AC inlet **60** by power lines APL**2**, ANL**2**.

(29) AC inlet **60** receives AC power supplied from an AC charging station (not shown) external to vehicle **1**. AC inlet **60** is connectable with a charging connector provided at a tip of a charging cable of the AC charging station. The AC power received by AC inlet **60** is supplied to AC charger **22** through power lines APL**2**, ANL**2**.

(30) AC charger **22** includes a charging circuit **23** and a sub-DC/DC converter **24**. In the present embodiment, charging circuit **23** and sub-DC/DC converter **24** are arranged on different substrates and are electrically connected by power line **27**.

(31) Charging circuit **23** includes a filter circuit, a PFC (Power Factor Correction) circuit, a smoothing capacitor, and a high-voltage DC/DC converter, which are not shown. The filter circuit is electrically connected to AC inlet **60** via fuse **84**. Fuse **84** is configured to interrupt a current path when a current exceeding its rated current flows. Fuses **85**, **86**, which will be described below, also have a configuration similar to that of fuse **84**. For the rated current, however, fuses are configured differently. The filter circuit removes noise contained in the AC power supplied from AC inlet **60** and outputs the AC power without noise to the PFC circuit. The PFC circuit rectifies and boosts the AC power with noise removed by the filter circuit and outputs the resultant AC power to the smoothing capacitor, and also brings the input current closer to a sine wave, thereby correcting a power factor. The PFC circuit may be various PFC circuits. The PFC circuit may be a rectifier having no power factor correction function. The smoothing capacitor smooths voltage fluctuations in the DC power received from the PFC circuit. The smoothed DC power is supplied to the high-voltage DC/DC converter and sub-DC/DC converter **24**. The high-voltage DC/DC converter converts the voltage of the DC power smoothed by the smoothing capacitor into a voltage (e.g., over 200 V) suitable for charging of main battery **11**, and then, supplies the voltage to power lines APL**1**, ANL**1**. Charging circuit **23** corresponds to an example of the “third power converter” according to the present disclosure.

(32) Sub-DC/DC converter **24** converts the voltage of the DC power smoothed by the smoothing capacitor into a voltage to be supplied to low-voltage auxiliary device **40**, and supplies the converted electric power to power line EL. Sub-DC/DC converter **24** has fuse **85** between power line EL and sub-DC/DC converter **24**. Sub-DC/DC converter **24** has a power capacity (the capacity to supply a current to power line EL) lower than the power capacity of main DC/DC converter **21**.

Power consumption of sub-DC/DC converter **24** is smaller than power consumption of main DC/DC converter **21**. Sub-DC/DC converter **24** corresponds to an example of the "second power converter" according to the present disclosure.
(33) DC relay **25** is provided between battery pack **10** and DC inlet **70**. Specifically, DC relay **25** has one end electrically connected to power lines PL, NL and the other end electrically connected to power lines CPL, CNL. Power lines CPL, CNL electrically connect DC inlet **70** to the other end of DC relay **25**, DC relay **25** switches between open/close states in accordance with a control signal from charging integration ECU **26**. When DC relay **25** is closed, the electric power supplied from DC inlet **70** can be supplied to battery pack **10**.
(34) DC inlet **70** receives DC power supplied from a DC charging station (not shown) external to vehicle **1**. DC inlet **70** is connectable with a charging connector provided at a tip of a charging cable of the DC charging station. The DC power received by DC inlet **70** is supplied to battery pack **10** through DC relay **25**.
(35) Power lines CPL, CNL are provided with a temperature sensor Ts. Temperature sensor Ts detects the temperatures of power lines CPL, CNL and outputs a signal indicating a detection result to charging integration ECU **26** through a temperature detection line.
(36) Charging integration ECU **26** includes a CPU (Central Processing Unit), a memory, and an I/O port, which are not shown. The memory includes a ROM (Read Only Memory) and a RAM (Random Access Memory) and stores a program or the like executed by the CPU. The CPU deploys the program stored in the ROM to the RAM and executes the program. The CPU executes predetermined arithmetic processing based on various signals input from the I/O port and information stored in the memory, and based on the result of the arithmetic processing, controls main DC/DC converter **21**, AC charger **22** (charging circuit **23**, sub-DC/DC converter **24**), and DC relay **25**. Such control can be processed not only by software, but also by purpose-built hardware (electronic circuit).
(37) Higher-level ECU **100** is, for example, an EV-ECU. Higher-level ECU **100** includes a CPU, a memory, and an I/O port, which are not shown. The memory includes a ROM and a RANI and stores a program or the like executed by the CPU. The CPU deploys the program stored in the ROM to the RAM and executes the program. The CPU performs predetermined arithmetic processing based on various signals input from the I/O port and information stored in the memory, and based on the result of the arithmetic processing, controls each device such that vehicle **1** enters a desired state. The CPU controls, for example, Fr_PCU **30**, Rr_PCU **31**, SMRs **12**, **13**, CHRs **14**, **15**, low-voltage auxiliary device **40**, high-voltage auxiliary device **50**, and solar charger **90**. Such control can be processed not only by software, but also by purpose-built hardware (electronic circuit).
(38) Higher-level ECU **100** and charging integration ECU **26** are configured to communicate with each other through a communication line. Charging integration ECU **26** controls main DC/DC converter **21**, AC charger **22**, and DC relay **25** based on information from higher-level ECU **100**.
(39) Vehicle **1** configured as described above includes power supply unit **20** in which a plurality of vehicle-mounted devices (main DC/DC converter **21**, AC charger **22**, DC relay **25**, and charging integration ECU **26**) are accommodated in housing **28**, as described above. The functions of the plurality of vehicle-mounted devices are integrated into a unit, and accordingly, can save more space and have a lower cost than when the plurality of vehicle-mounted devices are arranged individually.
(40) When the functions are to be integrated into a unit, however, the plurality of vehicle-mounted devices are accommodated in the same housing **28**, and accordingly, a problem associated with the heat generated in each vehicle-mounted device may become significant. In particular, main DC/DC converter **21**, charging circuit **23**, and sub-DC/DC converter **24** may generate a large amount of heat in operation. When such devices are arranged adjacent to each other, thus, the risk of failure may increase due to thermal interference between the devices. It is conceivable that main DC/DC

converter **21**, charging circuit **23**, and sub-DC/DC converter **24** may be arranged in different tiers of housing **28**. Considering the ease of mounting of power supply unit **20** on vehicle **1**, however, there is a demand for preventing an increase in the height of power supply unit **20** (the height of the vehicle in the height direction). Also, each of main DC/DC converter **21**, charging circuit **23**, and sub-DC/DC converter **24** has a large number of components and includes a large-mass magnetic component, leading to a mass heavier than that of any other vehicle-mounted device. Thus, there is also a demand for arranging main DC/DC converter **21**, charging circuit **23**, and sub-DC/DC converter **24** in the lowest possible tiers such that the center of gravity of power supply unit **20** is located on the lower side of housing **28**.

(41) In the present embodiment, thus, main DC/DC converter **21**, charging circuit **23**, and sub-DC/DC converter **24** are arranged in the tiers on the lower side of housing **28**. Then, main DC/DC converter **21** and sub-DC/DC converter **24** are arranged in the same tier in housing **28**. Charging circuit **23** is then arranged in a tier different from that of main DC/DC converter **21** and sub-DC/DC converter **24**. Charging integration ECU **26** operates main DC/DC converter **21** and sub-DC/DC converter **24** in a mutually exclusive manner. In other words, charging integration ECU **26** does not operate one of main DC/DC converter **21** and sub-DC/DC converter **24** when operating the other, and does not operate main DC/DC converter **21** and sub-DC/DC converter **24** simultaneously. Accordingly, the amount of heat generated from main DC/DC converter **21** and sub-DC/DC converter **24** can be reduced more than when main DC/DC converter **21** and sub-DC/DC converter **24** are operated simultaneously. This can reduce thermal interference between main DC/DC converter **21** and sub-DC/DC converter **24** while they are arranged in the same tier of housing **28**.

(42) Charging circuit **23** is arranged in a tier different from that of main DC/DC converter **21** and sub-DC/DC converter **24** because charging circuit **23** may be required to operate simultaneously with main DC/DC converter **21** and sub-DC/DC converter **24**. Specific control of each of during traveling of vehicle **1**, during AC charging, and during DC charging will be described below.

(43) Control During Traveling of Vehicle

(44) FIG. **2** is a diagram for illustrating control of power supply unit **20** during traveling of vehicle **1**. FIGS. **2** and FIGS. **3** to **5**, which will be described below, schematically show main battery **11**, power supply unit **20**, low-voltage auxiliary device **40**, and AC inlet **60**.

(45) Housing **28** of power supply unit **20** is made of, for example, aluminum or the like. A plurality of tiers are defined by partition walls **29** in housing **28**. Specifically, when power supply unit **20** is mounted on vehicle **1**, partition walls **29** extending in the front-rear direction of vehicle **1** are provided, and a plurality of tiers are defined by partition walls **29**. In other words, the plurality of tiers are formed to be stacked in the height direction of vehicle **1** in mounting of power supply unit **20** on vehicle **1**. In the present embodiment, housing **28** has three tiers. The lowermost tier is also referred to as “first tier”, the intermediate tier is also referred to as “second tier”, and the uppermost tier is also referred to as “third tier”. The “tier” in the present embodiment corresponds to an example of the “accommodation space” according to the present disclosure.

(46) Partition wall **29** has a refrigerant passage through which refrigerant flows. Since partition wall **29** has the refrigerant passage, each vehicle-mounted device accommodated in housing **28** can be cooled. Partition wall **29** may have a heat-insulating material in place of the refrigerant passage. Since partition wall **29** has the heat-insulating material, thermal interference between the vehicle-mounted devices across the tiers can be reduced.

(47) In the present embodiment, charging circuit **23** is arranged in the first tier. Main DC/DC converter **21** and sub-DC/DC converter **24** are arranged in the second tier. DC relay **25** and charging integration ECU **26** are arranged in the third tier. Although charging circuit **23** and sub-DC/DC converter **24** are included in AC charger **22**, charging circuit **23** and sub-DC/DC converter **24** can be arranged in different tiers by arranging charging circuit **23** and sub-DC/DC converter **24** on different substrates, as described above.

(48) During traveling of vehicle **1**, charging integration ECU **26** stops AC charger **22** (charging circuit **23** and sub-DC/DC converter **24**). Charging integration ECU **26** operates main DC/DC converter **21** to convert electric power of main battery **11**, and supplies the converted electric power to low-voltage auxiliary device **40** (power line EL), as indicated by an arrow AR**1**. During traveling of vehicle **1**, main DC/DC converter **21** and sub-DC/DC converter **24** are not operated simultaneously, thus avoiding a problem of the amount of heat generation which is associated with the simultaneous operation of main DC/DC converter **21** and sub-DC/DC converter **24**.
(49) Control During AC Charging
(50) FIGS. **3** and **4** are diagrams for illustrating control of power supply unit **20** during AC charging. In the present embodiment, charging integration ECU **26** switches control depending on electric power required by low-voltage auxiliary device **40** (i.e., power consumption of low-voltage auxiliary device **40**) which is required during AC charging. FIG. **3** shows a flow of electric power supply to low-voltage auxiliary device **40** when power consumption Pa of low-voltage auxiliary device **40** is less than a threshold Pth. FIG. **4** shows a flow of electric power supply to low-voltage auxiliary device **40** when power consumption Pa of low-voltage auxiliary device **40** is not less than threshold Pth. Threshold Pth is a value determined based on the power capacity of sub-DC/DC converter **24** (the capacity to supply electric power to power line EL). Threshold Pth can be set as appropriate within the range below the power capacity of sub-DC/DC converter **24**.
(51) When power consumption Pa of low-voltage auxiliary device **40** is less than threshold Pth, charging integration ECU **26** stops main DC/DC converter **21** and operates sub-DC/DC converter **24** to supply electric power supplied from AC inlet **60** to low-voltage auxiliary device **40**. Charging integration ECU **26** divides electric power supplied from AC inlet **60** into electric power to be supplied to main battery **11** and electric power to be supplied to low-voltage auxiliary device **40** (power line EL). Specifically, charging integration ECU **26** operates charging circuit **23** to convert electric power supplied from AC inlet **60** into charging power of main battery **11**, and supplies the converted electric power to main battery **11** (arrow AR**2**). Charging integration ECU **26** also operates charging circuit **23** and sub-DC/DC converter **24** to convert electric power supplied from AC inlet **60** into electric power to be supplied to low-voltage auxiliary device **40**, and supplies the converted electric power to low-voltage auxiliary device **40** (arrow AR**3**).
(52) When power consumption Pa of low-voltage auxiliary device **40** is not less than threshold Pth, charging integration ECU **26** stops sub-DC/DC converter **24** and operates main DC/DC converter **21**, and supplies electric power of main battery **11** to low-voltage auxiliary device **40**. Charging integration ECU **26** operates charging circuit **23** to convert the electric power supplied from AC inlet **60** into charging power of main battery **11**, and supplies the converted electric power to main battery **11** (arrow AR**4**). Charging integration ECU **26** also operates main DC/DC converter **21** to convert electric power of main battery **11** into electric power to be supplied to low-voltage auxiliary device **40**, and supplies the converted electric power to low-voltage auxiliary device **40** (arrow AR**5**).
(53) When power consumption Pa of low-voltage auxiliary device **40** is less than threshold Pth, charging integration ECU **26** does not operate main DC/DC converter **21** while operating sub-DC/DC converter **24**, as described above. When power consumption Pa of low-voltage auxiliary device **40** is not less than threshold Pth, charging integration ECU **26** does not operate sub-DC/DC converter **24** while operating main DC/DC converter **21**. In this manner, main DC/DC converter **21** and sub-DC/DC converter **24** are not operated simultaneously, thus avoiding a problem of the amount of heat generation which is associated with the simultaneous operation of main DC/DC converter **21** and sub-DC/DC converter **24**.
(54) Power consumption of sub-DC/DC converter **24** is smaller than power consumption of main DC/DC converter **21**. Thus, when power consumption Pa of low-voltage auxiliary device **40** is less than threshold Pth, that is, when the amount of electric power supplied from sub-DC/DC converter **24** can cover power consumption Pa of low-voltage auxiliary device **40**, a decrease in the charging

efficiency of main battery **11** can be reduced while supplying electric power to low-voltage auxiliary device **40** (power line EL) by stopping main DC/DC converter **21** and operating sub-DC/DC converter **24**.
(55) Control During DC Charging
(56) FIG. **5** is a diagram for illustrating control of power supply unit **20** during DC charging.
(57) During DC charging, charging integration ECU **26** stops AC charger **22** (charging circuit **23** and sub-DC/DC converter **24**). During DC charging, charging integration ECU **26** closes DC relay **25**. Thus, the electric power supplied from DC inlet **70** is supplied to main battery **11** through DC relay **25** (arrow AR**6**). Charging integration ECU **26** also operates main DC/DC converter **21** to convert the electric power of main battery **11** into electric power to be supplied to low-voltage auxiliary device **40**, and supplies the converted electric power to low-voltage auxiliary device **40** (arrow AR**7**). During DC charging, main DC/DC converter **21** and sub-DC/DC converter **24** are not operated simultaneously, thus avoiding a problem of the amount of heat generation which is associated with the simultaneous operation of main DC/DC converter **21** and sub-DC/DC converter **24**.
(58) Process Performed by Charging Integration ECU
(59) FIG. **6** is a flowchart showing the procedure of control of power supply unit **20**. The process shown in the flowchart of FIG. **6** is repeatedly performed by charging integration ECU **26** for each control cycle. Although description will be given of the case where each step (the step is abbreviated as "S" below) of the flowchart shown in FIG. **6** is implemented through software processing by charging integration ECU **26**, the step may be partially or entirely implemented by hardware (electronic circuit) formed in charging integration ECU **26**.
(60) At S**1**, charging integration ECU **26** determines whether vehicle **1** is traveling. For example, charging integration ECU **26** may determine whether vehicle **1** is traveling based on information received from higher-level ECU **100**. When determining that vehicle **1** is traveling (YES at S**1**), charging integration ECU **26** moves the process to S**2**. When determining that vehicle **1** is not traveling (NO at S**1**), charging integration ECU **26** moves the process to S**3**.
(61) At S**2**, charging integration ECU **26** operates main DC/DC converter **21** and stops sub-DC/DC converter **24**. By operating main DC/DC converter **21**, charging integration ECU **26** converts electric power of main battery **11** into electric power to be supplied to low-voltage auxiliary device **40** and supplies the converted electric power to low-voltage auxiliary device **40** (power line EL).
(62) At S**3**, charging integration ECU **26** determines whether DC charging is being performed. For example, charging integration ECU **26** determines whether DC charging is being performed, based on the presence or absence of connection of the charging connector to DC inlet **70**. When determining that DC charging is being performed (YES at D**3**), charging integration ECU **26** moves the process to S**4**. Determining that DC charging is not being performed (NO at S**3**), charging integration ECU **26** moves the process to S**5**.
(63) At S**4**, charging integration ECU **26** operates main DC/DC converter **21** and stops sub-DC/DC converter **24**. Charging integration ECU **26** operates main DC/DC converter **21** to convert electric power of main battery **11** into electric power to be supplied to low-voltage auxiliary device **40**, and supplies the converted electric power to low-voltage auxiliary device **40** (power line EL). Charging integration ECU **26** keeps DC relay **25** closed. In start of DC charging, charging integration ECU **26** switches DC relay **25** from the open state to the close state.
(64) At S**5**, charging integration ECU **26** determines whether AC charging is being performed. For example, charging integration ECU **26** determines whether AC charging is being performed, based on the presence or absence of connection of the charging connector to AC inlet **60**. When determining that AC charging is being performed (YES at S**5**), charging integration ECU **26** moves the process to S**6**. When determining that AC charging is not being performed (NO at S**5**), charging integration ECU **26** moves the process to RETURN.
(65) At S**6**, charging integration ECU **26** determines whether power consumption Pa of low-voltage

auxiliary device **40** is not less than threshold Pth. When power consumption Pa is less than threshold Pth (NO at S**6**), charging integration ECU **26** moves the process to S**7**. When power consumption Pa is not less than threshold Pth (YES at S**6**), charging integration ECU **26** moves the process to S**8**.
(66) At S**7**, charging integration ECU **26** stops main DC/DC converter **21** and operates sub-DC/DC converter **24**. During AC charging, charging integration ECU **26** also operates charging circuit **23**. By operating charging circuit **23** and sub-DC/DC converter **24**, charging integration ECU **26** converts electric power supplied from AC inlet **60** into electric power to be supplied to low-voltage auxiliary device **40**, and supplies the converted electric power to low-voltage auxiliary device **40** (power line EL).
(67) At S**8**, charging integration ECU **26** operates main DC/DC converter **21** and stops sub-DC/DC converter **24**. During AC charging, charging integration ECU **26** also operates charging circuit **23**. By operating charging circuit **23**, charging integration ECU **26** converts electric power supplied from AC inlet **60** into electric power for charging main battery **11**, and supplies the converted electric power to main battery **11**. By operating main DC/DC converter **21**, charging integration ECU **26** converts electric power of main battery **11** into electric power to be supplied to low-voltage auxiliary device **40**, and supplies the converted electric power to low-voltage auxiliary device **40** (power line EL).
(68) FIG. **7** shows the operation states of main DC/DC converter **21**, charging circuit **23**, and sub-DC/DC converter **24**. FIG. **7** shows the operation states of main DC/DC converter **21**, charging circuit **23**, and sub-DC/DC converter **24** during traveling of vehicle **1**, during AC charging, and during DC charging.
(69) During traveling of vehicle **1**, charging circuit **23** and sub-DC/DC converter **24** are stopped (not operated) and main DC/DC converter **21** is operated.
(70) During AC charging, the operation states of main DC/DC converter **21**, charging circuit **23**, and sub-DC/DC converter **24** are varied depending on the relation between power consumption Pa of low-voltage auxiliary device **40** and threshold Pth. When power consumption Pa of low-voltage auxiliary device **40** is less than threshold Pth, charging circuit **23** and sub-DC/DC converter **24** are operated, and main DC/DC converter **21** is stopped. When power consumption Pa of low-voltage auxiliary device **40** is not less than threshold Pth, charging circuit **23** and main DC/DC converter **21** are operated, and sub-DC/DC converter **24** is stopped.
(71) During DC charging, charging circuit **23** and sub-DC/DC converter **24** are stopped, and main DC/DC converter **21** is operated.
(72) As described above, power supply unit **20** mounted on vehicle **1** according to the present embodiment includes a plurality of vehicle-mounted devices, specifically, main DC/DC converter **21**, AC charger **22**, DC relay **25**, and charging integration ECU **26**, in housing **28**, and the functions of the vehicle-mounted devices are integrated. The functions of the vehicle-mounted devices are integrated into a unit, and accordingly, space and cost can be reduced more than when the vehicle-mounted devices are arranged individually.
(73) AC charger **22** includes charging circuit **23** and sub-DC/DC converter **24**, which are arranged on different substrates. Charging circuit **23** is electrically connected to sub-DC/DC converter **24** by power line **27**. Charging circuit **23** and sub-DC/DC converter **24** can be operated simultaneously, for example, in AC charging. Charging circuit **23** and sub-DC/DC converter **24** are arranged on different substrates, and accordingly, charging circuit **23** and sub-DC/DC converter **24** can be arranged in different tiers of housing **28**. This can avoid thermal interference due to the simultaneous operation of charging circuit **23** and sub-DC/DC converter **24**, which are arranged in the same tier.
(74) Main DC/DC converter **21** and sub-DC/DC converter **24** are arranged in the same tier of housing **28**. Main DC/DC converter **21** and sub-DC/DC converter **24** are operated in a mutually exclusive manner. In other words, charging integration ECU **26** does not operate main DC/DC

converter **21** and sub-DC/DC converter **24** simultaneously. Accordingly, the amount of heat generated from main DC/DC converter **21** and sub-DC/DC converter **24** can be reduced more than when main DC/DC converter **21** and sub-DC/DC converter **24** are operated simultaneously.
(75) An increase in the height of power supply unit **20** can be reduced more by arranging main DC/DC converter **21** and sub-DC/DC converter **24** that can be operated in a mutually exclusive manner in the same tier of housing **28** than by arranging main DC/DC converter **21** and sub-DC/DC converter **24** in different tiers. This can increase ease of mounting of vehicle **1** on power supply unit **20**.
(76) Charging circuit **23** is arranged in a tier different from that of main DC/DC converter **21** and sub-DC/DC converter **24**. Charging circuit **23** may need to be operated simultaneously with main DC/DC converter **21** and sub-DC/DC converter **24**. Thus, arranging charging circuit **23** in a tier different from that of main DC/DC converter **21** and sub-DC/DC converter **24** can reduce thermal interference due to the simultaneous operation.
(77) DC relay **25** and charging integration ECU **26** are arranged in a tier different from those of main DC/DC converter **21**, charging circuit **23**, and sub-DC/DC converter **24** that generate a large amount of heat in operation. This can reduce thermal interference with DC relay **25** and charging integration ECU **26** by main DC/DC converter **21**, charging circuit **23**, and sub-DC/DC converter **24**.
VARIATIONS
(78) Description has been given of the example in which a plurality of tiers are defined by partition walls **29** in housing **28**. The plurality of tiers are formed to be stacked in the height direction of vehicle **1** when power supply unit **20** is mounted on vehicle **1**. However, it suffices that a plurality of accommodation spaces for accommodating the vehicle-mounted devices can be defined by partition walls **29**, and how to define the accommodation spaces is not limited to the formation in which the accommodation spaces are stacked in the height direction of vehicle **1**.
(79) For example, a plurality of accommodation spaces may be defined by providing partition walls **29** extending in the height direction of vehicle **1** in mounting of power supply unit **20** on vehicle **1**. Also, in mounting of power supply unit **20** on vehicle **1**, partition wall **29** extending in the front-rear direction of vehicle **1** and partition wall **29** extending in the height direction of vehicle **1** may be provided together to define a plurality of accommodation spaces.
(80) Also in the above case, main DC/DC converter **21** and sub-DC/DC converter **24** arranged in the same accommodation space can be operated in a mutually exclusive manner, thus achieving effects similar to those of the embodiment.
(81) Although the present disclosure has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the scope of the disclosure being interpreted by the terms of the appended claims.

## Claims

1. A power supply unit, comprising: a first power converter; a second power converter; a controller that controls the first power converter and the second power converter; and a housing that has a plurality of accommodation spaces defined by a partition wall, the housing accommodating the first power converter, the second power converter, and the controller, wherein the first power converter and the second power converter are arranged in a same accommodation space of the housing, the controller operates the first power converter and the second power converter in a mutually exclusive manner, the power supply unit is mounted on a vehicle configured to perform AC charging of charging a main battery mounted on the vehicle with AC power supplied from an AC power supply external to the vehicle, the first power converter converts electric power of the main battery into electric power to be supplied to an auxiliary device mounted on the vehicle, the second power converter converts electric power supplied from the AC power supply into electric power to

be supplied to the auxiliary device, the power supply unit further comprises a third power converter that converts the AC power into electric power for charging the main battery, the third power converter is arranged in an accommodation space different from that of the first power converter and the second power converter, the controller controls the third power converter, the second power converter has a power capacity lower than a power capacity of the first power converter, and in execution of the AC charging, when power consumption of the auxiliary device is smaller than a threshold, the controller operates the third power converter to charge the main battery, operates the second power converter to supply electric power to the auxiliary device, and stops the first power converter.

2. The power supply unit according to claim 1, wherein in execution of the AC charging, when the power consumption of the auxiliary device is greater than the threshold, the controller operates the third power converter to charge the main battery, operates the first power converter to supply electric power to the auxiliary device, and stops the second power converter.

3. A power supply unit, comprising: a first power converter; a second power converter; a controller that controls the first power converter and the second power converter; and a housing that has a plurality of accommodation spaces defined by a partition wall, the housing accommodating the first power converter, the second power converter, and the controller, wherein the first power converter and the second power converter are arranged in a same accommodation space of the housing, the controller operates the first power converter and the second power converter in a mutually exclusive manner, the power supply unit is mounted on a vehicle configured to perform AC charging of charging a main battery mounted on the vehicle with AC power supplied from an AC power supply external to the vehicle, the first power converter converts electric power of the main battery into electric power to be supplied to an auxiliary device mounted on the vehicle, the second power converter converts electric power supplied from the AC power supply into electric power to be supplied to the auxiliary device, the power supply unit further comprises a third power converter that converts the AC power into electric power for charging the main battery, the third power converter is arranged in an accommodation space different from that of the first power converter and the second power converter, the controller controls the third power converter, the second power converter has a power capacity lower than a power capacity of the first power converter, and in execution of the AC charging, when power consumption of the auxiliary device is greater than a threshold, the controller operates the third power converter to charge the main battery, operates the first power converter to supply electric power to the auxiliary device, and stops the second power converter.

4. A power supply unit, comprising: a first power converter; a second power converter; a controller that controls the first power converter and the second power converter; and a housing that has a plurality of accommodation spaces defined by a partition wall, the housing accommodating the first power converter, the second power converter, and the controller, wherein the first power converter and the second power converter are arranged in a same accommodation space of the housing, the controller operates the first power converter and the second power converter in a mutually exclusive manner, the power supply unit is mounted on a vehicle configured to perform AC charging of charging a main battery mounted on the vehicle with AC power supplied from an AC power supply external to the vehicle, the first power converter converts electric power of the main battery into electric power to be supplied to an auxiliary device mounted on the vehicle, the second power converter converts electric power supplied from the AC power supply into electric power to be supplied to the auxiliary device, the power supply unit further comprises a third power converter that converts the AC power into electric power for charging the main battery, the third power converter is arranged in an accommodation space different from that of the first power converter and the second power converter, the vehicle is configured to perform DC charging of charging the main battery with DC power supplied from a DC power supply external to the vehicle, the power supply unit further comprises a relay for supplying the DC power to the main battery, and the relay

is accommodated in an accommodation space different from the accommodation space of the first power converter and the second power converter and the accommodation space of the third power converter.