

Development of Rechargeable Power Source LiB-AID E500

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ABSTRACT

The rechargeable power source LiB-AID E500 was developed by combining a lithium-ion battery and an inverter unit to create a power source that can support various types of electrical equipment used in everyday life.

The goals for this product were a design and ease of use that can appeal to a wide range of users. The use of inverter technology provides an electrical performance that enables a high-quality power supply as well as parallel and assist operation support for electrical equipment with high-starting power. In addition, a lightweight resin full-cover configuration using a monocoque frame structure achieves a compact and lightweight form while at the same time securing strength. Furthermore, enhancement of the cooling structure efficiency and optimization of the fan layout realized a high level of quietness.

1. Introduction

The market penetration rate among individuals for mobile terminals such as smartphones has exceeded 80%⁽¹⁾, and these devices are becoming important in people's daily lives. The capacities of the batteries used in these devices are increasing to enable use for longer times, but it is also not uncommon for mobile batteries to be carried to compensate for insufficient power. There is a growing need for electricity in various situations such as for everyday or leisure use, both day and night, indoors and outdoors, and demand is appearing for power sources that enable people to freely use electricity.

Meanwhile, LED lighting is spreading, electrical equipment is becoming more energy efficient, and devices that can be used with even a little power are proliferating. This is increasing the opportunities for users to want a little electric power in previously unplugged situations.

This paper introduces the LiB-AID E500 (hereafter, "E500") that was developed to meet these demands, and describes the technology used to realize various user-friendly features, such as high-quality electricity output⁽²⁾ with a compact and lightweight form and parallel operation with an engine generator⁽³⁾.

2. Development Goals

2.1. Development Concept

Conventional generator users in Japan purchase generators as power supplies for lighting and tools at

construction and other sites, or for backup applications in the event of a disaster. Therefore, generator usage has tended to be more for commercial purposes than household use. However, diversifying interests are expanding the situations in which electricity is needed on the go, such as glamping, staying overnight in Kei car type RVs, stargazing, and musical activities. Looking at everyday life, digital still cameras and video cameras are used on a daily basis, and electric tools are even used for gardening, mainly by the middle-aged and elderly. However, even in these cases, engine generators are limited to outdoor use and need fuel, oil, and other maintenance, so usage is limited.

A power supply that can meet these various user demands for electricity should be small, lightweight, quiet, and easy to use. In addition, good usability is also needed to support outdoor operating environments such as for music and other outdoor activities (Fig. 1), and for use in living rooms or other indoor or narrow spaces.

The concept for this development was "a new form of portable power supply," and the development goals were as follows:

- (1) Intuitive operation
- (2) High-electricity quality that can support various types of electrical equipment
- (3) Portability that enables convenient carrying

2.2. Design

The E500 took the image of Honda's highly reliable first generator, the E300 shown in Fig. 2(a), as a product that supplies electricity, and applied "Neo Modern Compact

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Design” as the design concept. “Neo Modern” refers to modernizing the shape of a long-familiar form to create something that is both new yet familiar. A component color scheme and “Compact” design shape were then applied to realize an approachable exterior design that makes users want to freely carry around the product.

A preliminary design with a simple surface quality and configuration was created based on the E300 shape, and terminal processing was applied to create a balanced shape that combines gentle roundness with edges as shown in Fig. 2(b). Here, “Neo Modern Compact Design” was expressed by the combination of the main color in the front and back panels, the gray of the center part, and a shape with more rounded corners.

The cooling performance, mass productivity, and the usability of the socket panel and handle of this preliminary design were then further refined to realize the finished E500 shown in Fig. 2(c).

Black and white were set as less-assertive and more versatile color variations in addition to the red color symbolic of Honda power products (Fig. 3).

The goal of these effects was to achieve use of the E500 by a wide range of users in various situations.

2.3. System Configuration and Features

The main functions of the E500 are power supply and

charging as shown in Fig. 4. The power supply block is equipped with AC output sockets to support various types of equipment, and also DC output USB ports for charging mobile terminals. The charging block (500 g) was made a separate unit to reduce the main unit weight, and can connect to both a household outlet charger and an automobile accessory socket charger.

Figure 5 shows the E500 system, and Table 1 shows the specifications of the completed unit. Combination of a lithium-ion battery, inverter unit, and USB unit achieved a configuration that can output both AC 100 V and DC 5 V, and realized a highly quiet power source that can be used even indoors and at night. The specific features of the E500 are as follows:

- (1) Intuitive interface
- (2) Parallel operation and assist operation to support various



Fig. 3 Color variations

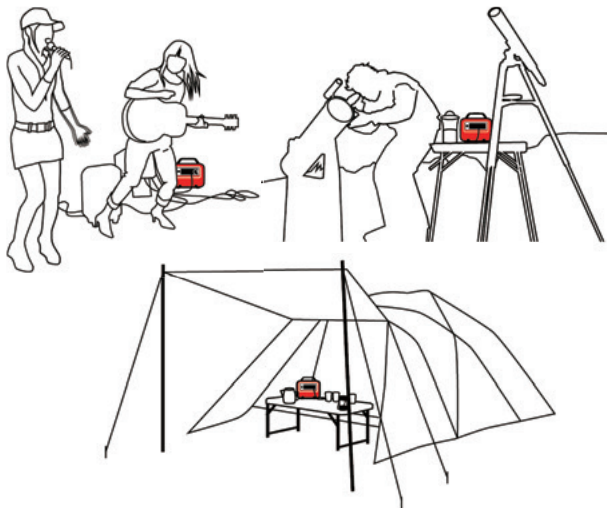


Fig. 1 Image of using the E500

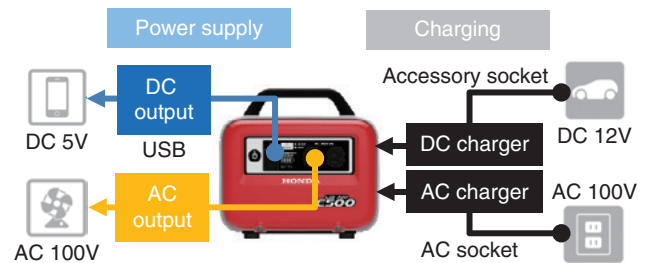


Fig. 4 E500 major functions



(a) E300 (b) Preliminary design (c) E500

Fig. 2 Design concept

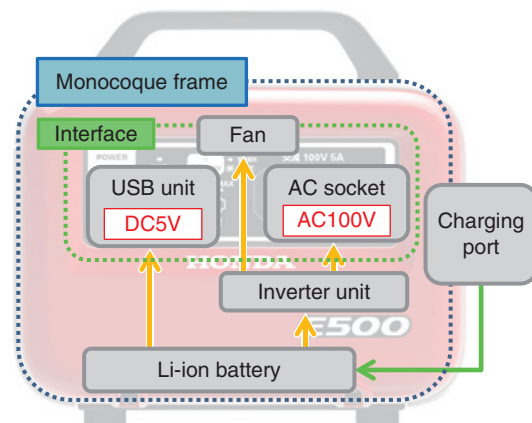


Fig. 5 System configuration

Table 1 Specifications of the E500

Item	Specification
Output AC voltage (V)	100
Frequency (Hz)	50/60
Rated output power (VA)	300
Maximum output power (VA)	500
Output DC voltage (USB) (V)	5
Rated output power (USB) (W)	10 (5 × 2)
Dimensions (L/W/H) (mm)	266 × 182 × 248
Mass (kg)	5.3
Sound power level (dB)	L _{WA} 42
Battery capacity (Wh)	377

types of electrical equipment

- (3) Lightweight (5.3 kg) and strong monocoque frame structure
- (4) Optimized cooling mechanism that realizes a small size and low noise

3. Introduction of Technology

3.1. User Interface

Figure 6 shows the control panel appearances. Figure 6(a) shows the front panel, which arranges the buttons and indications needed when supplying power, and Fig. 6(b) shows the side panel, which arranges the switches and connectors used only for setup before supplying power.

The button layout uses an easily recognizable configuration with the operation order proceeding from left to right based on the user interface principle⁽⁴⁾. In addition, the Power button (round) and AC OUT button (square) have different shapes and the USB ports are located between the buttons to let users intuitively perform smooth and doubt-free power supply operations.

Battery level and electrical output displays, warning lamps that inform of errors, and other indicators are located together in the center of the panel, enabling to check the

E500 operating status at a glance.

Furthermore, the control panel surface uses an embossed membrane, plus tact switches as shown in Fig. 7, to realize both a neat appearance and a good operational feeling.

3.2. Support for Various Electrical Equipment

The E500 can be operated in the two modes of parallel operation and assist operation, which is an expanded form of parallel operation, in order to support various types of electrical equipment. These two modes can be selected by the AC OUT button pressing time.

3.2.1. Parallel operation

The E500 may be unable to supply sufficient power when using equipment with high power consumption. However, the E500 uses parallel operation technology⁽³⁾, so the power of two units can be supplied simply by connecting the units with a previously released special cable, as shown in Fig. 8, to support cases in which the power of one E500 unit is insufficient.

3.2.2. Assist operation

Some types of electrical equipment require starting power in excess of the noted rated power consumption, in the same manner as a motor. Generator users who use

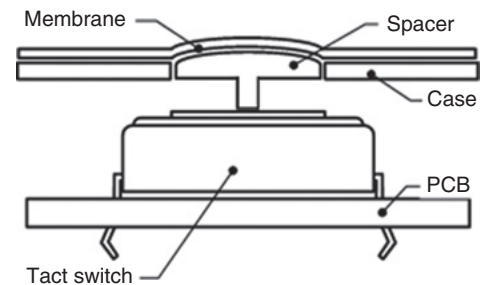
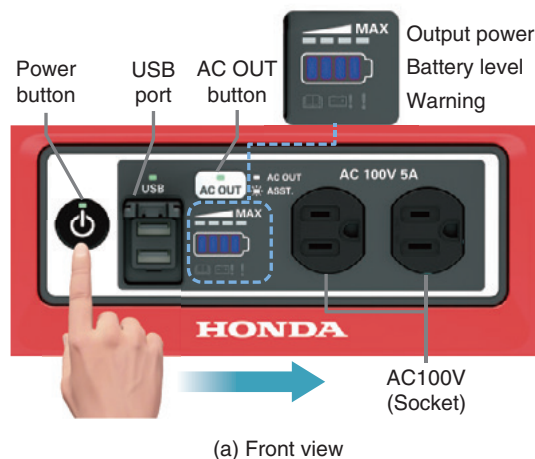
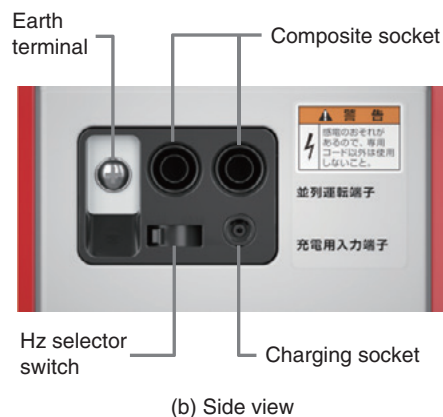


Fig. 7 Structure of buttons on front panel



(a) Front view



(b) Side view

Fig. 6 Control panel design

this type of equipment use the equipment starting power as a criterion for selecting an engine generator, and it may be necessary in some cases to select an engine generator with higher power output than wanted. In response to this need, the E500 can perform assist operation to compensate the power supply of the master engine generator while performing parallel operation with a Honda engine generator (with built-in inverter).

Figures 9(a) and 9(b) show the respective power-sharing loads during parallel operation and assist operation using the E500 and an engine generator. During simple parallel operation, power from the E500 battery is consumed at equipment startup and also during subsequent equipment operation. However, by using assist operation, the E500 only needs to perform assist output for a short time at startup, enabling efficient use of the battery power.

In addition to the previously described parallel operation, assist start-timing detection and power supply adjustment are also needed to realize assist operation. The engine generator output voltage drops during electrical equipment startup as shown in Fig. 10. The E500 performs assist output when it detects that the engine generator output voltage has dropped to a certain threshold value or less.



Fig. 8 E500 parallel operation

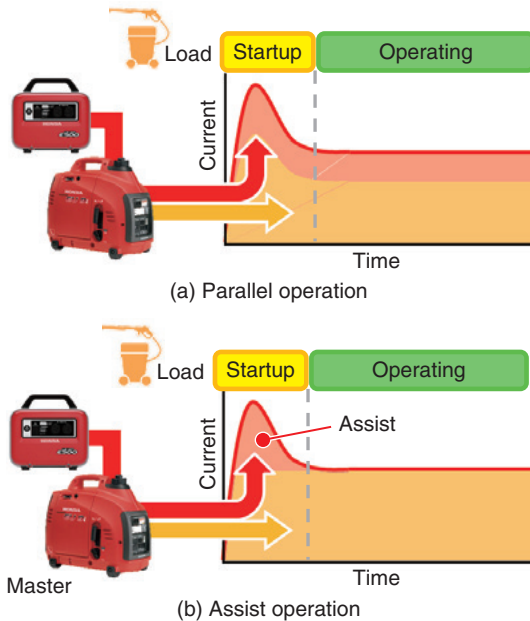


Fig. 9 Parallel operation and assist operation

Unlike normal parallel operation, during assist operation the power supply balance between the E500 and the engine generator is not kept uniform, and instead the E500 output voltage is varied according to the current value flowing to the equipment in order to assist the power shortage of the engine generator.

Figure 11 shows the change in the generated power output when a piece of electrical equipment with a built-in 700 W output motor is connected to a Honda engine generator (EU9i) rated at 900 VA and started up. In this case, the power supplied by the engine generator does not reach the power needed to start the equipment, so the engine generator stops due to an overload. This means that the electrical equipment cannot be used with only that engine generator. Next, Fig. 12 shows the results when the E500 performs assist operation for the same engine generator. The assist function lets the E500 assist (compensate) the EU9i power shortage during equipment startup, enabling to use the equipment.

3.3. Bathtub Type Monocoque Structure

Figure 13 shows the E500 frame structure. In addition to achieving a small size and light weight, the frame also needs to protect the internal electronic parts. Therefore,

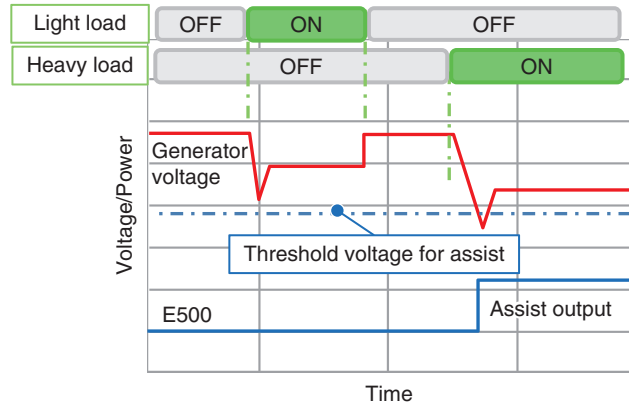


Fig. 10 Assist start timing

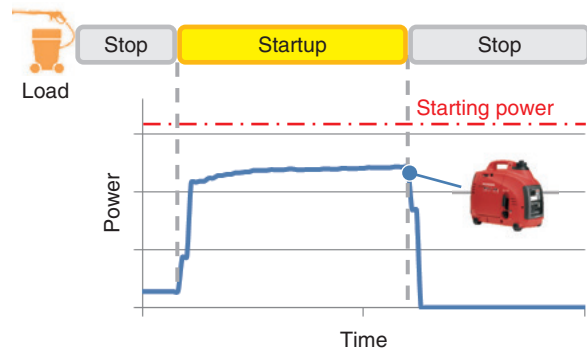


Fig. 11 Generator power shortage for 700 W load

the frame used a two-part monocoque frame structure (lightweight resin full-cover structure) consisting of an upper cover and an under cover, and was given a bathtub shape to increase the strength and protect the internal parts. This free-standing shape reduced the need to fix electronic parts with screws or other fixtures, and also increased the ease of assembly.

Furthermore, structures that support the control panel, inverter, and other parts and cooling air passages were built into the monocoque frame shape. This increased the surface rigidity, making it possible to use lightweight, inexpensive and easily available polypropylene instead of special resin materials.

3.4. Cooling Mechanism

When the E500 transforms the DC voltage of the battery into AC voltage, the internal loss from the battery, inverter, and other parts generates heat, so cooling is needed. The E500 uses the two cooling methods, by frame structure and by fan.

3.4.1. Cooling by the frame structure

Figure 14 shows the cooling structure. A cooling air inlet is provided on the bottom with a cooling air outlet

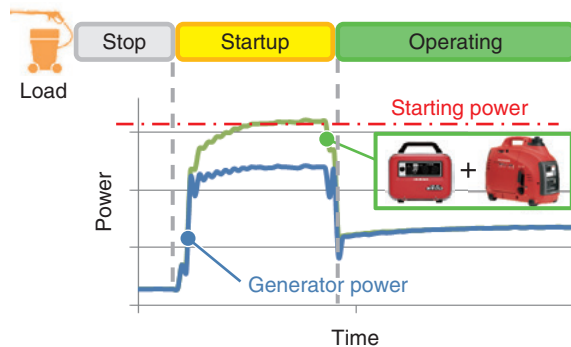


Fig. 12 Result of assist operation

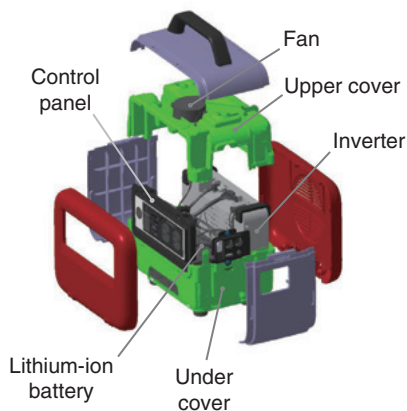


Fig. 13 Monocoque frame structure

on the top to make use of the chimney effect to promote natural ventilation. In addition, the heat generated from the inverter unit is conveyed to the metal case as part of the heat-radiation structure. This enabled an achievement of sufficient cooling without increasing the number of typically used parts such as heat sinks, which helped to reduce the size and weight.

3.4.2. Cooling by a cooling fan

The following three points were reflected to the design specifications to perform efficient cooling.

- Location of the inverter part that reaches the highest temperature at the cooling air inlet
- Formation of local cooling paths near the high-temperature parts of the inverter
- Use of a blower type fan that can secure sufficient air flow even in narrow spaces

Figure 15 shows the numerical analysis results of the flow field inside the chassis during fan operation. This shows that a concentrated flow forms around the local high-temperature part of the inverter and air stagnation around



Fig. 14 Cooling air flow

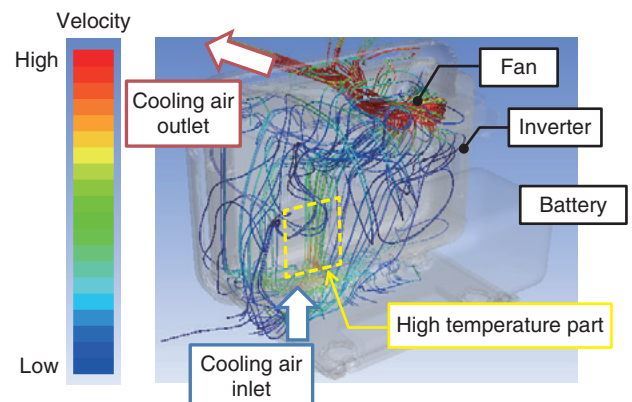


Fig. 15 CFD analysis of internal air flow

the battery is reduced, indicating that the intended cooling air flow is achieved with a single fan. The E500 fan operates only when the internal temperature rises, which helps to minimize battery consumption due to fan operation.

In addition, the fan is located in the center of the chassis, away from the ventilation air outlet in order to shield the fan operation noise. This achieved good quietness performance with a noise value L_{WA} of 42 dB as shown in Table 1. Furthermore, the E500 realizes approximately 50% lower mass and volume compared to competing products with a battery of similar capacity, as shown in Figs. 16 and 17.

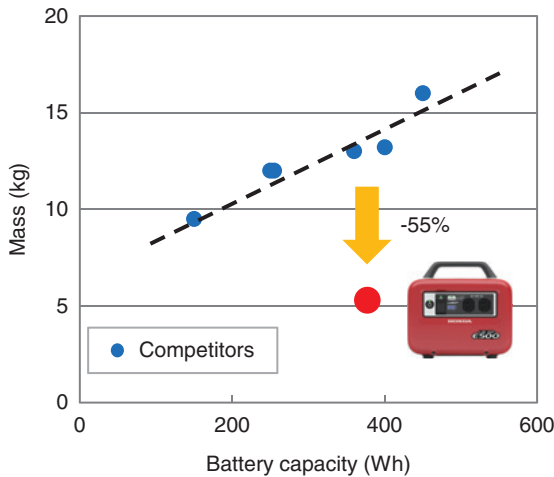


Fig. 16 Comparison of mass with competitors

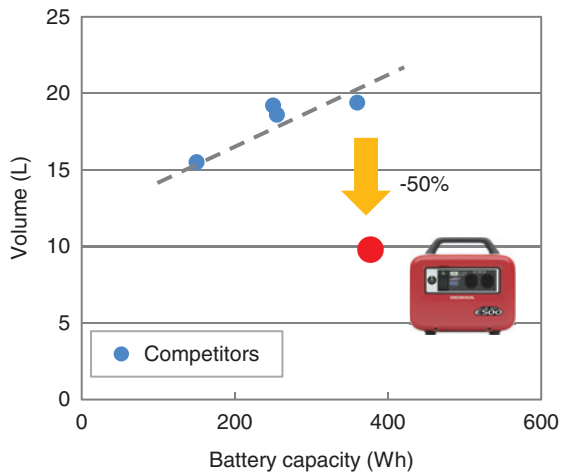


Fig. 17 Comparison of volume with competitors

4. Conclusion

The rechargeable power source LiB-AID E500 was developed by combining a lithium-ion battery and an inverter unit. “Neo Modern Compact Design” was used as

the design concept to realize an approachable design. In addition, design and manufacturing were performed from the viewpoint of usability in consideration of potential use situations, and the following results were achieved.

- (1) Intuitive interface
- (2) Parallel operation and assist operation to support various electrical equipment
- (3) Lightweight and strong monocoque frame structure
- (4) Optimized cooling mechanism that realizes a small size and low noise

The LiB-AID E500 is a product that will become an integral part of people’s lives, and use is expected in various situations to help expand the range of user activities.

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