METHOD TO DETERMINE CAPACITY OF A BATTERY

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This method to determine capacity of a battery computes capacity in current value and then converts it into capacity in power value, or computes capacity in power value and then converts it into current value. This method to determine capacity of a battery detects either discharge current or charge current or both, and computes capacity of battery in current value, which is then converted into capacity in power value by way of multiplication by the correcting constant which varies in accordance with capacity in current value. This method to determine capacity of a battery detects battery voltage or detects either discharge current or charge current or both of the battery, then computes battery capacity in power value, and converts capacity in power value so computed into capacity in current value by way of multiplication by the correcting constant which varies in accordance with capacity in power value.
FIG. 2

FCC

DESIGN CAPACITY

RSOC = 50%

4.8 Ah (56 Wh)

4.9 Ah
FIG. 3

START

\[ n = 1 \] RSOC in current value is inputted to the converter

\[ n = 2 \] The correcting constant for RSOC is picked out.

\[ n = 3 \] RSOC in current value is converted into RSOC in power value by being multiplied by the correcting constant.
FIG. 4

START

[n = 1] RSOC in power value is inputted to the converter.

[n = 2] The correcting constant for RSOC is picked out.

[n = 3] RSOC in power value is converted into RSOC in current value by being multiplied by the correcting constant.
FIG. 5

START

\[ n = 1 \]
Charge capacity in current value is inputted to the converter

\[ n = 2 \]
The correcting constant for charge capacity is picked out.

\[ n = 3 \]
Charge capacity in current value is converted into charge capacity in power value by being multiplied by the correcting constant.
FIG. 6

START

\[ n = 1 \]
Charge capacity in power value is inputted to the converter.

\[ n = 2 \]
The correcting constant for charge capacity is picked out.

\[ n = 3 \]
Charge capacity in power value is converted into charge capacity in current value by being multiplied by the correcting constant.
FIG. 7

1. FCC is detected by fully charging the battery.
2. The correcting constant is picked out based on RSOC in current value.
3. RSOC in current value is converted into RSOC in power value by being multiplied by the correcting constant.
4. ASOC in current value is computed by multiplying RSOC in current value by FCC/DC.
5. ASOC in power value is computed by multiplying RSOC in power value by FCC/DC.
METHOD TO DETERMINE CAPACITY OF A BATTERY

[0001] This application is based on application No. 094074 filed in Japan on Mar. 30, 2000, the content of which is incorporated hereinto by reference.

BACKGROUND OF THE INVENTION

[0002] This invention relates to a method to determine capacity such as the remaining battery capacity of a battery in value of electric current as well as in value of electric power.

[0003] Data such as the remaining capacity of a battery used as the source for electronic device such as computer is required to be determined in value of electric current or and in value of electric power. The remaining capacity in electric current value is determined by subtracting the multiplication of discharge current from the fully charged battery capacity. The remaining battery capacity in electric power value is determined by subtracting the multiplication of discharge power from the fully charged battery capacity. The remaining capacity in electric current value is calculated from the multiplied value of discharge current. The remaining capacity in electric power value is computed from multiplication of the product of multiplication of current value by voltage. The remaining power in a battery should always be computed by multiplication of battery voltage by discharge current, followed by multiplication of the product of multiplication so conducted, as the voltage of a battery constantly changes as battery continues to discharge.

[0004] As stated above, the means differ as to calculating the remaining capacity of a battery in electric current value and in electric power value; so each means should be practiced separately in order to obtain the remaining capacity both in current value and in power value. In such a case calculation requires a very complicated system and heavy workload, and results in technical and financial difficulties, which is considered as a shortcoming of the above stated means.

[0005] The present invention has been developed in order to overcome the above stated shortcoming. The primary object of this invention is to provide a method which determines capacity of a battery in value of both electric current and of electric power in a very simple way.

SUMMARY OF THE INVENTION

[0006] Method to determine capacity of a battery, according to the present invention cites either to calculate capacity in electric current value alone and then to convert it into electric power value, or to calculate capacity in electric power value alone and then to convert it into electric current value. Method according to the present invention calculates capacity in electric current value and converts it into capacity in electric power value. Alternatively the method calculates capacity in electric power value and converts it into capacity in electric current value.

[0007] The method of determining battery capacity calls for either detecting the discharging electric current or detecting the recharging current or both, and thus determines battery capacity in terms of electric current value. Capacity in electric current value so determined is multiplied by the correcting constant which varies in accordance with current capacity and thus capacity in electric power value is determined.

[0008] In the present method, for example, the remaining capacity of a battery in electric current value is first calculated from the multiplication of discharge current of the battery and then the remaining capacity in power value is calculated by multiplying the remaining capacity in current value so calculated by the correcting constant which varies in accordance with the remaining capacity in current value. In this way the remaining battery capacity is computed as the relative remaining capacity.

[0009] According to the method of determining capacity of a battery, capacity of a battery is first computed in electric power value by detecting the battery voltage and multiplication of discharge current or charge current or both. Capacity in electric power value so calculated is converted into capacity in electric current value by way of being multiplied by the correcting constant which varies in accordance with capacity in power value.

[0010] In the present method, for example, the remaining capacity of a battery in power value is first calculated from the multiplication of discharge power and then the remaining capacity in current value is computed by multiplying the remaining capacity in power value by the correcting constant which varies in accordance with the remaining capacity in electric power value. In this way the remaining battery capacity is calculated as the relative remaining capacity.

[0011] The method of the present invention to determine capacity of a battery is distinctly different from others in a way that it calculates battery capacity in electric current value as well as electric power value in a very simple way. The reason is that by this method capacity is determined by calculating capacity in current value and converting it into power value or calculating capacity in power value and then converting it into capacity in current value. In this method of the present invention capacity in electric power value is calculated by multiplying capacity in electric current value by the correcting constant which varies in accordance with capacity in power value. Or capacity in current value is calculated by multiplying capacity in power value by the correcting constant which varies in accordance with capacity in power value. In this way the method of the present invention assures a simple and inexpensive device for the circuit in order to obtain battery capacity in electric power value as well as in electric current value.

[0012] The above and further objects and features of the invention will more fully be apparent from the following detailed description with accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 shows a block diagram of the circuit, used for the embodiment of this invention to determine capacity of a battery.

[0014] FIG. 2 shows an example of a battery to be used for determining battery capacity.

[0015] FIG. 3 shows a flow chart to illustrate steps of converting RSOC in electric current value into RSOC in electric power value.
FIG. 4 shows a flow chart to illustrate steps of converting RSOC in electric power value into RSOC in electric current value.

FIG. 5 shows a flow chart to illustrate steps of converting full charge capacity in current value into that in power value.

FIG. 6 shows a flow chart to illustrate steps of converting full charge capacity in power value into that in current value.

FIG. 7 shows a flow chart to illustrate steps of computing ASOC in both current value and power value from RSOC in current value.

FIG. 1 shows a block diagram of a circuit stored in a battery pack for the purpose of determining battery capacity according to the present method. A battery pack storing this circuit is to be attached to an electronic device such as a computer, supplying electric power as well as communicating data such as battery capacity to the electronic device. An electronic device detects the remaining capacity of battery 1, with information communicated from the battery pack at the prescribed sampling timing.

The battery pack shown in FIG. 1 has a consumed current/voltage detector 2, which detects consumed current of battery 1 and converts it into voltage; a voltage detector 3, which detects voltage of battery 1; a first A/D converter 4, which converts analogue signals outputted at the consumed current/voltage detector 2 into digital signals; a second A/D converter 5, which converts analogue signals outputted at the voltage detector 3 into digital signals; a multiplier 6, which multiplies consumed electric power of battery 1 from signals outputted at the first A/D converter 4 and at the second A/D converter 5, or multiplies consumed current outputted at the first A/D converter 4; a low battery detector 7, which detects voltage at the completion of discharge based on signals outputted at the first A/D converter 4; a timer 8, which operates trigger at prescribed intervals to the first A/D converter 4 and the second A/D converter 5 in order to convert analogue signals into digital signals; the remaining capacity calculator 9, which computes the remaining capacity by subtracting consumed electric power or consumed electric current from fully charged battery capacity; converter 10, which converts value in power into value in current or the other way round, of the remaining battery capacity computed at the remaining capacity calculator 9, or of the multiplication outputted at the multiplier 6; SMBus data communication processor 11, which communicates and outputs the remaining battery capacity to an electronic device such as computer. This battery pack is attached to an electronic device such as computer with SMBus interposed in between.

The consumed current/voltage detector 2 is provided with an electric current resistor with low resisting power connected to battery 1 in series and at the same time provided with a differential amplifier to amplify the voltage generated at the two ends of the resistor. This consumed current/voltage detector 2 outputs current in value flowing to battery 1 as voltage outputted at the differential amplifier. Voltage outputted at the differential amplifier is the product of multiplication of the amount of current flowing to battery 1 by the constant.

Voltage is outputted at consumed current/voltage detector 2 and voltage detector 3 in analogue signals. The first A/D converter 4 and the second A/D converter 5 convert analogue signals into digital signals and output as such, in order for digital processing to compute the remaining capacity and make correction. The first A/D converter 4 and the second A/D converter 5 convert voltage signals communicated into digital signals upon trigger movement directed by timer 8, and output as such.

The multiplier 6 multiplies either consumed current or consumed power when battery 1 is discharged; and multiplies either charge current or charge power when battery 1 is charged. This circuit preferably be used for multiplying current value, as multiplication of current is performed more easily than multiplication of power. To multiply electric power, multiplication of product of the multiplication of current value by power value should be performed. For this purpose the output at the first A/D converter 4 and the second A/D converter 5 should be multiplied. To multiply current value, however, multiplication of the output at the first A/D converter 4 alone serves the purpose, which proves to be comparatively simple computation. Another possible way is to multiply power at this circuit and then convert the multiplication in current value into that in power value.

At the remaining capacity calculator 9 the remaining capacity of battery 1 is calculated by subtracting the multiplication of consumed electric current or consumed electric power from capacity of fully charged battery, so-called FCC (full charge capacity) or design capacity and then the remaining capacity so compute is outputted to the converter 10. FCC which represents a capacity of fully charged battery 1 is computed from the multiplication of charge current. Not all electric current used for charging battery 1 is expended for the said purpose, so FCC, which signifies capacity when fully charged, is rightly calculated from multiplying the multiplication of charge current by the charge efficiency factor. There are several ways of indicating the remaining battery capacity; RSOC (Relative State Of Charge) considers the capacity as 100% charged when a battery is fully recharged; ASOC (Absolute State Of Charge) considers the design capacity as 100% charged; or RC (Remaining Capacity) is calculated by the absolute value of Ah or Wh. As for the way to output in relative value, there are also a couple of ways available; on is a way to calculate in current value and another is one in power value.

At the circuit illustrated in FIG. 1 the remaining capacity of battery 1 is detected. However the remaining capacity is not always necessary to be detected. There are other performances possible, as multiplying charge current or multiplying discharge current of battery 1, and calculation by discharged power or its multiplication. As the remaining capacity is determined by subtracting discharge capacity from fully charged capacity, the remaining capacity calculator is indispensable in this circuit. Multiplication of discharge current or charge current, or multiplication of discharge power or charge power can be performed at the multiplier 6, so the signals to perform these calculations are outputted from the multiplier 6 directly to the converter 10.

The low battery detector 7, supplied with the output from the second A/D converter 5, detects whether the voltage of the battery 1 drops below the discharge termina-
tion voltage. This detector transmits the discharge termination voltage signal to the converter 10 when the voltage of battery 1 actually drops below the discharge termination voltage.

[0028] The converter 10 converts the remaining battery capacity communicated from the remaining capacity calculator 9, from power value into current value or from current value into power value. The remaining capacity in power value is calculated by multiplying the remaining capacity in current value by the correcting constant and the remaining capacity in current value is calculated by multiplying the remaining capacity in power value by the correcting constant. The correcting constants are stored in memory attached to the converter 10. The Table 1 shows the correcting constants stored in memory at the converter 10, which correct the remaining capacity in current value into the remaining capacity in power value.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>RSOC (mAh)</td>
</tr>
<tr>
<td>Correcting Constants</td>
</tr>
</tbody>
</table>

[0029] Shown in the table above are the correcting constants which correct the remaining capacity in current value into that in power value. RSOC signifies the relative remaining capacity established when fully charged capacity of a battery is considered as 100% charged, RSOC in current value is converted into RSOC in power value when multiplied by the correcting constant in the table which is picked out in accordance with RSOC in current value. When RSOC in current value stands at 0 or 100%, the correcting constant is 100% that is 1; when RSOC in current value stands somewhere between 0-100 the correcting constant becomes less than 100% that is less than 1. The device which stores the correcting constants for RSOC in current value in memory attached to the converter 10 converts electric current value into electric power value in an easy manner. A table of correcting constants is not necessary when function for RSOC in current value is inputted in memory at the converter 10. In such a case function works for converting current value into power value.

[0030] The correcting constants which converts current into power are computed by discharging a battery which is the same type as used in the circuit in FIG. 1 as a sample and then so computed correcting constants are stored into memory. For example, the correcting constants are computed in the following way.

[0031] (1) Fully charged battery 1 is discharged at constant current till the remaining capacity becomes n%. RSOC in current value of battery 1 at this stage is considered to be n%.

[0032] (2) Then this battery 1, with no recharging, continues its discharge at constant power till it completes discharge. In such a case when discharge power is detected as m%, this m% is considered to be RSOC in power value.

[0033] (3) the correcting constant at which RSOC in current value stands at n% can be calculated by calculation of m/n outputs.

[0034] By setting n% at various points in this manner correcting constants for converting RSOC at 100-0% in current value into that in power value are computed. The correcting constants thus computed are stored as a table in memory at the converter 10, or function for correction is stored in memory at the converter. The converter 10 computes RSOC in power value by way of multiplying RSOC in current value by the correcting constant.

[0035] While the method stated above states how to convert RSOC in current value into RSOC in power value, there is a way to convert RSOC in power value into current value. In this case the correcting constant for RSOC at m% in power value should be computed by applying n/m as a correcting constant in step (3) stated above. The correcting constants are stored as a table or as function in memory at the converter 10. The converter 10 converts RSOC in power value into RSOC in current value by way of multiplying RSOC in power value by the stored correcting constant.

[0036] The way how the converter 10 converts RSOC in current value into RSOC in power value is stated above. The same converter can convert ASOC in current value into ASOC in power value, ASOC being the remaining capacity when nominal capacity so-called DC (Design Capacity) is considered as 100%. ASOC is computed from calculation of RSOC which then is converted into ASOC in the remaining capacity. The difference between RSOC and ASOC lies in the difference of full capacity upon which calculation is based. Therefore conversion is easily performed by the following equation.

\[ \text{ASOC} = \text{RSOC} \times \text{FCC} / \text{DC} \]

[0037] For example in the case when fully charged capacity FCC drops to 50% of DC, ASOC of battery 1 becomes one half capacity of RSOC. Standard value for ASOC which is 100% becomes twice more as in the case above.

[0038] In the circuit shown in FIG. 1 the output at the remaining capacity calculator 9 is communicated to the converter 10, thus the remaining capacity of battery 1 is inputted at the converter 10 either in current value or in power value. The method of the present invention to determine the capacity of a battery is not restricted to determination of the remaining capacity alone. Capacity of a battery could be the multiplication of discharge current or charge current. The multiplication can be performed either in power value or in current value and then converted by way of multiplication by the correcting constant. The correcting constants used in conversion are calculated by detecting electric power and electric current in charging or discharging a sample battery.

[0039] As illustrated in FIG. 2 when a battery with DC of 4.8 Ah and 56 Wh is charged to show the multiplication of charge current to be 4.9 Ah and then the same battery is discharged and from the multiplication of discharge current RSOC in current value is calculated to be 50%, the converter 10 computes RSOC in power value in the following way. RSOC in power value is calculated by way of multiplying RSOC in current value by the correcting constant. When RSOC in current value stands at 50%, the correcting constant should be 97% as read in the table. Therefore RSOC in power value is calculated in the following equation.

\[ \text{RSOC in power value} = \text{RSOC in current value} \times \text{correcting constant} \times 0.97 = 0.48 \]
Full charge capacity (Wh) of this battery is calculated as follows. As DC measured in Ah is 4.8 Ah and FCC is 4.9 Ah, FCC should be 4.9/4.8 times as much as DC. So FCC measured in Wh is computed as follows. This computation is performed at the converter 10.

\[ FCC(Wh) = 56 \text{ Wh} \times \frac{4.9}{4.8} = 57.16 \text{ Wh} \]

ASOC of this battery is calculated as follows. This equation is also performed at the converter 10.

\[ ASOC(\text{in current value}) = ASOC(\text{in power value}) \times \frac{\text{FCC}}{\text{DC}} \times \frac{50}{51} \]

\[ ASOC(\text{in power value}) = 48 \times \frac{50}{51} = 47.5 \text{ Wh} \]

RC (remaining capacity) of this battery measured in Ah and Wh is calculated as follows.

\[ RC(\text{in current value}) = \frac{\text{FCC(\text{in current value})} \times \text{ASOC(\text{in current value})}}{4.9} \times 50 = 4.45 \text{ Ah} \]

\[ RC(\text{in power value}) = \frac{\text{FCC(\text{in power value})} \times \text{ASOC(\text{in power value})}}{51} = 57.16 \text{ Wh} \times \frac{48}{51} = 27.43 \text{ Wh} \]

The circuit illustrated in FIG. 1 converts RSOC in current value into RSOC in power value following the steps shown in the flow chart below which is illustrated in the FIG. 3.

[In the step when n=1]

[In the step when n=2]

[In the step when n=3]

[In the step when n=4]

[In the step when n=5]

[In the step when n=6]

[In the step when n=7]

[In the step when n=8]

[In the step when n=9]

[In the step when n=10]
8. A method to determine capacity of a battery comprising the steps of:

- (1) detecting battery voltage and either discharge current or charge current of a battery or both;
- (2) computing battery capacity in power value;
- (3) computing capacity in current value by way of multiplying the capacity in power value so computed by the correcting constant which varies in accordance with capacity in power value.

9. A method to determine capacity of a battery according to claim 8, wherein the remaining capacity in power value is calculated from multiplication of discharge power and the remaining capacity in power value so calculated is multiplied by the correcting constant which varies in accordance with the remaining capacity in power value and thus the remaining capacity in current value is determined.

10. A method to determine capacity of a battery according to claim 9, wherein the remaining capacity of the battery is relative remaining capacity.

11. A method to determine capacity of a battery according to claim 8, wherein current flowing to the battery is detected by a consumed current/voltage detector which is electrically connected to the battery.

12. A method to determine capacity of a battery according to claim 11, wherein output voltage of the voltage detector and the consumed current/voltage detector is A/D converted into digital signals and then the remaining capacity is computed and corrected by using the digital signals.

13. A method to determine capacity of a battery according to claim 9, wherein the remaining battery capacity is computed by subtracting the multiplication of consumed power either from FCC, which signifies a fully charged battery capacity, or from design capacity.

14. A method to determine capacity of a rechargeable battery according to claim 3, wherein the computing step of correcting constants comprises the steps of:

- (1) discharging a fully charged battery at the constant current till the remaining capacity measures n%, at which the relative remaining capacity of the battery in current value is n%;
- (2) detecting m% of discharge power by complete discharging at the constant power without recharging, at which detected m% is the relative remaining capacity in power value; and
- (3) calculating m/n, at which the correcting constant at n% relative remaining capacity in current value is calculated.

15. A method to determine capacity of a battery pack, comprising the steps of:

- (1) detecting consumed current of the battery by converting into voltage at a consumed current/voltage detector;
- (2) detecting voltage of battery at a voltage detector;
- (3) converting analogue signals which are outputted at the consumed current/voltage detector into digital signals at a first A/D converter;
- (4) converting analogue signals which are outputted at the voltage detector into digital signals at a second A/D converter;
- (5) multiplying either consumed electric power of the battery based on the output signals of the first A/D

What is claimed is:

1. A method to determine capacity of a battery, comprising the steps of:

- (1) detecting either discharge current or charge current of the battery, or both;
- (2) computing capacity of the battery based on the detected electric current value;
- (3) computing capacity in power value by way of multiplying capacity in the computed current value by correcting constant which varies in accordance with capacity in current value.

2. A method to determine capacity of a battery according to claim 1, wherein the remaining capacity in current value is computed based on the multiplication of discharge current and then the remaining capacity in power value is computed by way of multiplying the remaining capacity in current value by the correcting constant which varies in accordance with the remaining capacity in current value.

3. A method to determine capacity of a battery according to claim 2, wherein the remaining capacity of the battery is relative remaining capacity.

4. A method to determine capacity of a battery according to claim 1, wherein current flowing to the battery is detected by a consumed current/voltage detector which is electrically connected to the battery.

5. A method to determine capacity of a battery according to claim 4, wherein output voltage of the consumed current/voltage detector is A/D converted into digital signals and then the remaining capacity is computed and corrected by using the digital signals.

6. A method to determine capacity of a battery according to claim 2, wherein the remaining battery capacity is computed by subtracting the multiplication of consumed current either from FCC (Full Charge Capacity), which signifies a fully charged battery capacity, or from design capacity.

7. A method to determine capacity of a rechargeable battery according to claim 3, wherein the computing step of correcting constants comprises the steps of:

- (1) discharging a fully charged battery at the constant current till the remaining capacity measures n%, at which the relative remaining capacity of the battery in current value is n%;
- (2) detecting m% of discharge power by complete discharging at the constant power without recharging, at which detected m% is the relative remaining capacity in power value; and
- (3) calculating m/n, at which the correcting constant at n% relative remaining capacity in current value is calculated.
converter and the second A/D converter or consumed current outputted at the first A/D converter by using a multiplier;

(6) detecting a discharge termination voltage based on the signals outputted at the second A/D converter by using a low battery detector;

(7) generating trigger for converting analogue signals into digital signals to the first A/D converter and the second A/D converter at the prescribed intervals by using a timer;

(8) computing remaining capacity by subtracting either consumed current or power from fully charged capacity by using a remaining capacity calculator;

(9) converting either the remaining capacity computed at the remaining capacity calculator or the multiplication outputted at the multiplier from current value into power value, or power value into current value, by using a converter;

(10) transmitting the remaining capacity to an electronic device at SMBus data communication processor.

16. A method to determine capacity of a battery pack cited in claim 15, wherein the battery pack is connected to the electronic device such as computer via SMBus.

17. A method to determine capacity of a battery pack cited in claim 15, wherein the consumed current/voltage detector outputs electric current of the battery as output voltage from a differential amplifier.

18. A method to determine capacity of a battery pack according to claim 15, wherein relative remaining capacity in current value is converted into that in power value by the steps comprising:

(1) inputting the relative remaining capacity in current value from the remaining capacity calculator into the converter;

(2) determining the correcting constant for the relative remaining capacity so inputted at the converter; and

(3) converting into the relative remaining capacity in current value by multiplying the relative remaining capacity in power by the correcting constant.

19. A method to determine capacity of a battery according to claim 15, wherein the steps to convert the relative remaining capacity in power value into the relative remaining capacity in current value are made up of:

(1) a step to communicate the remaining capacity in power value to the converter from the remaining capacity calculator;

(2) a step to pick out, at the converter, the correcting constant for the relative remaining capacity so communicated; and

(3) a step to multiply the relative remaining capacity in power value by the correcting constant to convert the relative remaining capacity in power value into that in current value.

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