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Performance of Battery Inspection Based on Full Charged and Discharged Method

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Abstract*-Nowadays, battery is one of the necessary consumables; as all mobile devices should use batteries as their power supply and the batteries will influence the service life of these mobile devices, it is necessary to monitor the batteries to protect the mobile devices. The study used the HT66F50 chip and a hardware circuit to test the capacity of the batteries and to display by a LC. In order the make sure the accuracy, the measurement method of the proposed device used the instrument "ImaxB8+" to measure the batteries with the same brand; take the battery of brand A as an example, its capacity marked in the product specification is 1500mAh, the proposed device and ImaxB8+ conduct the charging and discharging cycle test for 10 times; the measurement result of the average charging capacity is 1484.1mAh and the measurement result of the average discharging capacity is 1478.1mAh; the measurement result of the average charging capacity of ImaxB8+ is 1490.5mAh and the measurement result of the average discharging capacity of ImaxB8+ is 1487.8mAh. The errors of the batteries in all brands are within 1% and estimated accuracy is within the permissible range; the measurements are finished in 2 hours.

Key words: **battery service life displaying, charging index displaying, real-time charging/discharging current displaying**

I. INTRODUCTION

With the development and advance of technology, rechargeable secondary battery has gradually become the major trend in the market [1]. However, the currently available secondary batteries still have a lot of potential dangers and shortcomings [2]; as the available capacity of the battery will decrease after the battery is installed in a device and has been used for a period of time, the times of charging and discharging increase, or the battery is overcharged due to the poor quality of the charging device; all of the above reasons will influence the capacity of the battery and reduce its service life, and the service life of the battery will be limited because the usage frequency increases. Besides, the currently available chargers cannot show the real available capacity of the battery, so the actual usage situation is unknown and the safety of the battery cannot be controlled as well, which will indirectly result in the risk when we use other devices.

Most of the chargers can only provide basic charging function and display whether the battery is fully charged by a LCD, but cannot display the correct capacity and the internal damage situation of the battery; the proposed device can display the correct charging efficiency by percentage.

In order to provide users with a convenient device to use, the proposed device is designed to be directly installed in any charger to upgrade the function of the original one so no needs to purchase another new charger for use. When the battery is being charged, the LCD will display the real-time charging capacity; after the battery is fully charged, the proposed device will automatically disconnect the battery from the power supply and then use a buzzer to notify the user.

II. LITERATURE REVIEW

SOC estimation technology

The definition of SOC, as in equation (1), is the percentage of the remaining capacity Qr of the battery to the rated capacity Qrated of the battery:

$$\mathrm{SOC} = \left(\frac{Q_r}{Q_{rated}}\right) \times 100\% \qquad (1)$$

More specifically, the capacity unit of the battery is ampere-hour (Ah). The definition of the rated capacity is the total released electricity that a healthy and full battery is discharged to the safe cut-off voltage by 0.1C constant current [1]. The definition of the remaining capacity (Qr) is the total released electricity that a battery under a certain charging or discharging status is discharged to the safe cut-off voltage by 0.1 constant current.

During the charging and discharging processes of a battery, the internal chemical reaction of the battery is very complicated; there are many factors which may influence the capacity estimation of the battery; there are many relevant literature performing the estimation by means of measuring the parameters of the change of the battery's SOC[2]-[4]. The most frequently used estimation methods are as follows.

(1) Specific weight measurement

The specific weight measurement is to measure the change of the specific weight of the electrolyte in the battery to estimate the SOC of the secondary battery. The method is usually applied to measure a lead-acid battery [5]. However, the method is to measure the change of the electrolyte of the battery, so the method needs additional instruments. In this way, the cost will increase; thus, the method is not practical.

(2) Loaded voltage measurement

When a battery is supplying power to a device, the easiest way to measure the capacity is to use the loaded voltage. Fig. 1 is the relation between the terminal voltage of the Li secondary battery and it SOC; in general, the discharging voltage of the Li secondary battery is 4.2V and the cut-off voltage of the Li secondary battery is 3.0V. the higher the energy stored by the battery is, the higher the terminal voltage of the battery will be; if the battery releases energy, the terminal voltage of the battery will gradually decrease [6]. The loaded voltage measurement is to detect the voltage change to estimate the change of the voltage. The method should consider the type of the battery; besides, as the discharging current will vary with the load and different currents will result in different decreases of the terminal

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voltage; the higher the discharging current is, the more obvious the decrease of the terminal voltage will be. Thus, how the change of the current influences the SOC of the battery should be taken into account.

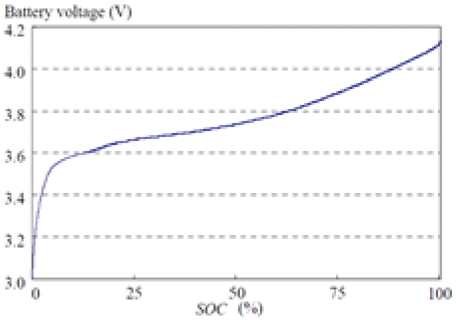

Fig.1 Relation between battery voltage and SOC

(3) Internal resistance measurement

The internal resistance measurement is to measure the internal resistance of a battery to estimate the current SOC of the battery. When the battery is being charged, the internal resistance of the battery will increase with the increase of the SOC of the battery; when the battery is being discharged, the internal resistance of the battery will decrease with the decrease of the SOC of the battery; therefore, the SOC of the battery can be measured only by determining its internal resistance. The concept of measuring the internal resistance of the battery is the major stream of the SOC measurement method over the last 10 years [7]. The integral method is based on Energy conversation law, but the internal resistance measurement is based on the characteristics of the material.

Fig.2 is the equivalent circuit of the internal resistance of the battery, where RM stands for the metal via resistance, RE stands for the electrochemical via resistance, CP stands for the capacitance of the battery, EC stands for the terminal voltage of the battery.

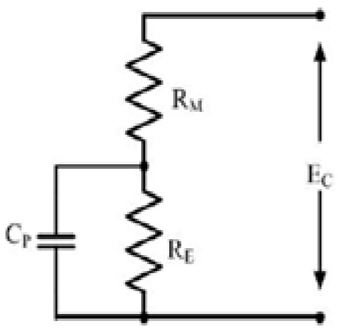

Fig.2 Equivalent circuit of internal resistance of battery

The circuit design of the internal resistance measurement is very complicated; if the measurement is required to be of high accuracy, an additional power supply is a must, which will increase the cost. The internal resistance measurement can actually measure the change status of the internal chemical material inside the battery, so measuring the internal resistance of the battery can provide the information about the overall status of the battery, including the aging status, electrolyte deterioration status, and other variables inside the battery.

(4) The Coulometric measurement

The Coulometric measurement is one of the most accurate methods for now; according to Energy conversation law, the energy inputted into the battery is always equal to the energy of the battery, which is used as the measurement standard to measure the current passing through the battery to calculate the product of which and the time so as to obtain the energy of the battery; then, after the loss during the energy conversion is modified, the remaining energy of the battery can be obtained [8]. However, the method also has its shortcoming; the charging/discharging process of the battery is the process of the change of the chemical material; the chemical material reaction process will be influenced by temperature and the value of the discharging current; therefore, the temperature influence and the current synergy effect will be considered.

As the coulometric measurement has theoretical basis instead of developing only for the characteristics of one kind of special battery, the coulometric measurement is applicable to all kinds of batteries. The object of the study is to develop a battery SOC measurement method, so the study should modify the coulometric method and use the principle of the coulometric measurement; during the charging and discharging processes, the values of the input current and output current were monitored; further, based on the environmental temperature and output current status, the available capacity was modified.

The proposed device uses the coulometric measurement; in order to accurately measure the available capacity and service life of the battery, it will be discharged to the cut-off voltage before changed; in order words, the battery will be fully discharged and be tested the real available capacity of the battery.

III. WORKING PRINCIPLE

(1) Battery performance displaying function

The battery service test measurement device is based on the charging loss feature of secondary battery; the charging of the battery is a curve function rather than a linear function; thus, the coulometric measurement, shown in Equation (2), is adopted to measure the battery parameters, and then the capacity of the battery is recorded after the battery is fully charged for the first time; next, the status of the battery is compared after the battery is fully charged for the second time with that of the previous time; then, the service life of the battery is tested in A_h as in equation (2).

$$A_h = \int_{t_{do}}^{t_{dn}} i_d(t) \cdot \qquad (2)$$

The situations can be classified into two types:

a. The secondary battery which has yet to be used:

Before the chemical structure of the batter not to be changed, the capacity of the battery is recorded for later comparison.

b. The used secondary battery

Since the chemical structure status of the batter is unknown, the initial capacity of the battery cannot be obtained accurately; thus, the capacity shown in the product

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specification of the battery should be referred; then, the value is input into the proposed device to conduct the service life performance (E) measurement as in equation (3).

$$E = \frac{Q_n}{Q} \times 100 \quad (3)$$

Q = Initial capacity Q_n =Capacity after used

(2) Charging index displaying function

In general, the capacity index is measured according to the output voltage of the battery; in fact, the index should be calculated based on the actual capacity of the battery when the battery is being charged; the study calculates the charging index of the battery via the D/A conversion of HT66F50, and then display the value on the LCD.

(3) Real-time battery charging/discharging current displaying function

The most frequently-used current charging device is constant current output; however, the study is not limited by which; with the coulometric measurement, the study is applicable to all kinds of charging devices, and then the real-time current can be measured via the D/A conversion calculation of HT66F50. Some chargers have a quick charge design; the function can immediately detect whether the battery is dangerous under quick charge so as to prevent the service life of the battery.

(4) Automatic disconnection function

As described in (2), the charging index is used to determine whether the battery is fully charged; if the charging index reaches 100%, the I/O interface will control the circuit breaker to disconnect the charger from the battery so as to prevent the battery from being overcharged and save the energy.

(5) Applicable to all kinds of batteries

The currently available batteries can be classified into many types due to different packing materials; the novel design of the study is applicable to all kinds of secondary batteries; afterward, the study will be applied to the batteries of various devices to protect these batteries, such as mobile phone, electric vehicle, wireless remote control device or medical equipment.

(6) Capacity information storage function

The study is combined with memory and is designed to be able to record the capacity value into the internal memory for the user to measure the secondary battery with the same specification without resetting the device, which is convenient for user.

IV. EXPERIMENTAL RESULTS

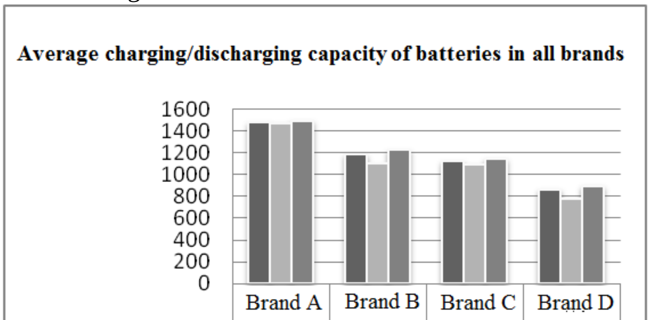
During the actual experiment process, the proposed device asked the user to input the capacity of the product specification of the battery; take the battery of brand A as an example, the capacity of the product specification is 1500mAh, shown in Fig. 3.1: afterward, the proposed device started to measure the real-time current, battery capacity, charging/discharging time and battery performance, shown in Fig. 3.2; when the charging and discharging processes were finished, the proposed device showed the final results to the user for the reference, shown in Fig. 3.a-3.c.

Fig.3.a

Fig.3.b

Fig.3.c

The measurement method of the proposed device was used to measure the average available charging capacity and available discharging capacity of the batteries of all brands; all batteries were brand-new and healthy; each charging/discharging cycle was conducted under 25°C to decrease the influence on the charging capacity and discharging capacity of the battery due to temperature. As shown in Fig. 4, the measured capacities of the batteries of brand A and brand C almost matched their product specifications; however, the measured discharging capacities of the batteries of brand B and brand D have over 10% error, shown in Fig. 5.



	Brand A	Brand B	Brand C	Brand D
Charge(mAh)	1484.1	1187.8	1128.2	867.2
Discharge(mAh)	1478.1	1101.5	1100.2	780.1
Capacity (mAh)	1500	1230	1150	900

Fig.4 Average charging/discharging capacity in batteries of all brands

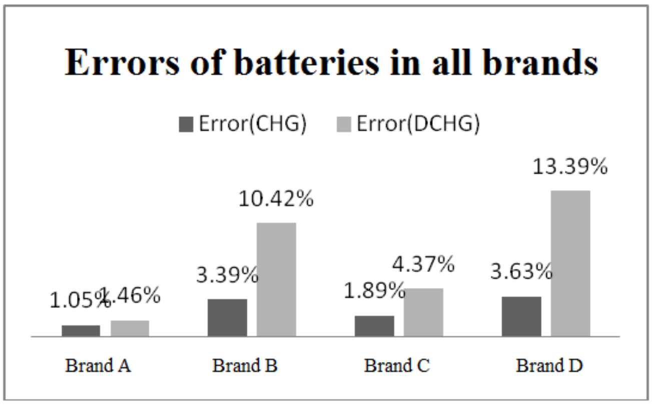


Fig.5 Errors of using battery cycle service life measurement system to measure batteries of all brands

To make sure the measurement method of the proposed device with high accuracy, the instrument "ImaxB8+" verified by National Applied Research Laboratories was utilized to conduct the measurements of the batteries with the same brand; the errors of the measurement results of the two

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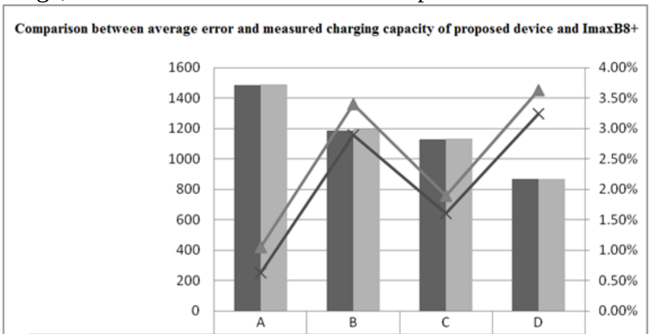
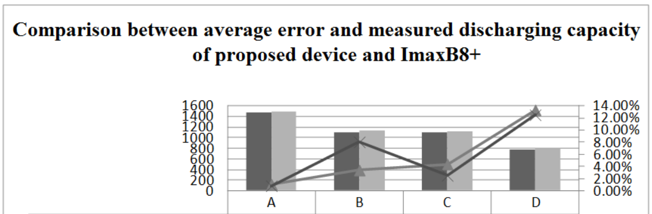
instruments are within 1%, shown in Fig. 6. The batteries of brand B have a significant difference, shown in Fig. 7. Although the estimated accuracy is within the permissible range, but it still needs to be further improved.



	A	B	C	D
measured Charge(mAh)	1484.1	1187.8	1128.2	867.2
ImaxB8+Charge(mAh)	1490.5	1194.4	1133.3	870.8
measured Error(CHG)	1.05%	3.40%	1.89%	3.63%
ImaxB8+Error(CHG)	0.63%	2.89%	1.61%	3.24%

Fig.6 Comparison between average error and measured charging capacity of proposed device and ImaxB8+



	A	B	C	D
measured Discharge(mAh)	1478.1	1101.5	1100.2	780.1
ImaxB8+Discharge(mAh)	1487.8	1131.1	1121.1	787.4
measured Error(DCHG)	1.05%	3.40%	4.37%	13.31%
ImaxB8+Error(DCHG)	0.81%	8.04%	2.51%	12.49%

Fig.7 Comparison between average error and measured discharging capacity of proposed device and ImaxB8+

V. CONCLUSION

All experiments of the study adopted healthy Li secondary batteries; according to these experiments, the average error of the charging data of the Li secondary batteries is lower than the average error of the discharging data of the Li secondary batteries; the reason of which may be that there is a discharging resistor in the circuit when the battery is being discharged, so some energy is consumed by the resistor. According to the experiment results, after 10 charging/discharging cycles, the charging/discharging in battery A and battery C are better, and their charging capacity and discharging capacity are close to their product specifications; on the contrary, the differences of the charging/discharging in battery B and battery D are nearly 5% or above.

The data of the measurement method of the proposed device is compared with that of ImaxB8+ balance charger manufactured by Fekodar Model Co. Ltd.; although the estimation accuracy is with the permissible range, it still needs further improvement. In the future, the studies can be conducted according to the following directions:

• Although the experiments in the paper adopt healthy batteries, but these experiments fail to consider the internal loss of the batteries; in the future, the experiments can be designed to estimate the internal loss caused by current.

• During the charging and discharging processes, some chemical energy of the battery will be converted into thermal energy, which results in the battery's temperature increase; the capacity of the battery may differ in the high and low temperature. Thus, to increase the accuracy, the influence on the capacity caused by temperature should be modified. In addition, the higher the temperature is, the higher the discharging rate is. As long as the loss of the battery increases, the available capacity of the battery will reduce. Hence, temperature plays a significant influence in the capacity of the battery, so it can be regarded as an important experiment parameter in the further study.

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