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CHARACTERISTICS ANALYSIS OF BATTERY USED IN EQUIPMENT FOR MONITORING AND REMOTE TRANSMISSION OF VITAL HUMAN PARAMETERS

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Abstract. ***Nowadays, the use of remote monitoring and transmission of vital parameters became extremely common, because these systems reduce the degree of risk among ill people and provide an additional time necessary for the intervention teams - in case of emergency action. Generally, these devices monitor and transmit data as values of blood pressure and the heart rate. This equipment permanently worn by the ill people have as sources of electric energy supply batteries or accumulators. The behavior of batteries and the parameters measurement for different operating states are defined as particularly important analyses, especially in terms of voltage and time. In this article we have analyzed two types of batteries (Lithium-Ion and Nickel-Metal Hydride) with different characteristics, using a monitoring device that measures the depth of discharge (DOD) while under load in our biomedical system. The battery characterizations were made while the system was operating measuring the body signs and transmitting the data.***

Keywords: depth of discharge, battery monitoring, heart rhythm, vital signs, biomedical system.

1. INTRODUCTION

For the system power supply of remote monitoring and transmission of vital parameters, we realized an analysis regarding the terms of time discharging under load, of two types of batteries, known as Lithium-Ion battery and respectively Nickel-Metal Hydride (NiMH).

1.1 Lithium-Ion Batteries (LIB)

LIB belongs to a family of rechargeable battery, where lithium ions are crossing from the negative electrode to the positive electrode in the discharging process and in the opposite sense, in the charging process. These are using graphite for anode and lithium oxide for cathode, the electrolyte being composed of $LiPF_6$ $LiBF_4$. This type of battery (lithium-ion) is, frequently, used to power the electronic portable devices. Also, these batteries are characterized as having the highest density of energy and holding a slow discharge when aren`t used [1].

1.2 Lithium-Ion batteries with Polymer electrolyte (LiPo)

LiPo cells track the history of lithium-ion and lithium-metal cells that have undergone ample improvements over time. In comparison to the two types, the LiPo battery is a LiB battery that uses instead of lithium salt liquid electrolyte, a solid polymeric electrolyte [2].

1.3 Nickel alkaline batteries

The alkaline nickel battery technology was invented by Waldmar Jungner in 1899. In 1932 the active materials were stored inside a porous nickel-plated electrode and in 1947 began the research for watertight NiCd batteries, which recombines the gases generated during internal submissions instead of removing them. These discoveries have led to modern NiCd battery that we use nowadays. Amongst rechargeable batteries, the NiCd remains a variant of use for applications like: portable radio, emergency medical devices, and professional video cameras. Over 50% of rechargeable batteries used for portable equipments are those based on NiCd [3].

1.4 Nickel-Metal hydride

Researches on nickel-metal hydride system began in the 70s as a mean of storing hydrogen for a Nickel Hydrogen battery. Alloys of metal hydrides were unstable in the environment of the cell and the desired performance characteristics could not be reached. For this reason, the process of development for battery NiMH has been slowed. New alloys were discovered in the late `80s which were stable enough to be used in a cell. Since the early '80s, nickel-metal hydride battery has been developed, mainly, in terms of energy density. Design engineers have shown that, NiMH, presents a potential for a greater density of energy [4].

2. CHARACTERISTICS OF BATTERY TYPES

2.1 Lithium-Ion Batteries

While supplying the load, the battery discharge process takes place over a period of time depending on the current consumed by the load, in which the Lithium ions (Li+) conduct the electrical current from the positive electrode to the negative electrode. Once the battery is discharged, it should be subjected to the charging process by feeding it from an external voltage source with a higher voltage value than the battery, forcing Lithium ions (Li+) to travel in the opposite direction. In this process the lithium ions will migrate from the positive electrode to the negative one, where are further incorporated into the porous material of the electrode – the process is named *intercalation*. The main components required in the operation of a lithium-ion battery are: the anode, the cathode and the electrolyte. The anode lithium-ion battery is made from carbon, the cathode from a metal oxide, and the electrolyte, usually, consists of an organic solvent or lithium salt. The most common material used for the anode manufacture is graphite.

The cathode is typically made from one of the three materials such as: layer of oxide (e.g. lithium cobalt), a poli-anion or lithium magnesium oxide. In the present case, the electrodes are defined as a mixture of organic carbonates such as - ethylene carbonate or diethyl carbonate which contain a lithium-ions complex. Depending on the chosen material, the voltage, the capacity, the service life, and the safety of a lithium-ion battery, all these parameters may vary dramatically. Currently, the new designs based on nanotechnology features have made possible the improvement of the performance among batteries. Furthermore, must be mentioned and considered the fact that lithium – Li, in the native state, is extremely reactive. Lithium-ion batteries compared to other types of batteries such as NiCd batteries, are more expensive, but work on a larger range of temperature with a higher density of energy, being in the same time, smaller and lightweight. The battery running time depends on the number of charge/discharge cycles, (500 - 1000 in the case of Lithium-ion batteries). Li-ion cells are available in various formats, which can generally be divided into four groups:

- small, cylindrical (solid body without terminals, such as those used in laptop batteries)
- large, cylindrical (solid body with large threaded terminals)
- plastic bag (soft body, flat, like those used in mobile phones)
- rectangular (semi hard plastic with large threaded terminals, often used in cans for traction vehicles [5].

Currently, new designs using nanotechnology features have made it possible to improve battery performance in general.

2.2 Lithium-Ion batteries with Polymer electrolyte (LiPo)

In the case of LiPo batteries, solid electrolyte can usually be classified as one of three types: dry SPE, gelled SPE and porous SPE. The dry SPE was the first used in prototype batteries around 1978 by Michel Armand from Domain University [6], [7] and in1985 by ANVAR and Elf Aquitaine in France and Hydro Quebec in Canada.

A LiPo battery has four main components: positive electrode, negative electrode, separator and electrolyte. The separator itself may be a polymer, such as a microporous film of polyethylene (PE) or polypropylene (PP); so even if the cell has a liquid electrolyte it will still contain a "polymeric" component. In addition, the positive electrode may be further broken down into three parts: lithium transition metal oxide (such as $LiCoO2$ or $LiMn2O4$), a conductive additive and a polymeric vinylidene fluoride binder (PVdF). The negative electrode has the same three parts, except for lithium metal oxide, which is replaced by carbon [8], [9].

An important feature of LiPo batteries is that they provide more energy than other types of lithium batteries, and are especially used in applications where weight and size are an essential feature such as; mobile phones or aircraft radio equipment.

2.3 Nickel alkaline batteries

The NiCd battery manufacturing technology has lost over the newer NiMh and Li-Ion battery technology, with their market share dropping by approx. 80%.

Some of the distinct advantages of NiCd batteries compared to other items are as fallow:

- quick and simple to load/charge;
- large number of charging/discharging cycles (when used correctly, the NiCd battery supports over one thousand charging/discharging cycles);
- excellent load/charge capacity, even at low temperatures;
- simple to be stored and transported (NiCd battery is supported by the most of air transport companies);
- easy to recharge after prolonged storage;
- safe in case of using it wrong usage;
- low price;
- can be found in a variety of sizes and performance.

It supports fast charging and also supports pulse charging. Consequently the NiCd battery, is the only one which performs best if it`s discharged periodically [6].

Some of the advantages of NiMH batteries are considered to be:

- has a capacity with 30% greater than that of NiCd battery;
- fewer “memory” problems than NiCd;
- has fewer toxic materials.

Unfortunately the NiMH battery shows some negative attributes compare to those based on NiCd, as example:

- number of cycles: NiMH battery is guaranteed for 500 charge/discharge cycles;
- reduced cycles of discharge – the battery life is directly proportional with the amplitude discharge.

NiMH batteries generates considerably more heat during charging and needs a considerably more complex algorithm for determining the "filling" than NiCd batteris, if thermal detection is not available. Above all, the NiMH battery can`t be charged as fast as NiCd; it’s charging time being almost double. The NiMH and NiCd batteries are affected by auto-discharging quite alot. The NiCd batteries loses are about 10% of its capacity in the first 24 hours, after this remaining at aprox.10% per month. Auto-discharging ratio for NiMH battery is about (1.5-2) greater. If you choos hydride type, which improves the binding with Hydrogen to reduce auto-discharging, it will result a lower battery capacity; as an observation, NiMH possesses a capacity of up to 30% higher than a NiCd battery of the same size. Instead, the price of MiMH batteries is nearly 30% higher. The price is not very important as it is necessary to have a large capacity and small size. High capacity NiCd batteries are however more economical [10].

3. DETERMINING THE PARAMETERS OF THE BATTERIES USED IN THE EQUIPMENT FOR MONITORING AND DEMOTE TRANSMISSION OF VITAL PARAMETERS

Battery testing aims at choosing the type of battery to power a system of monitoring vital parameters. For this we take into account the discharge time in the load, the dimensions and the weight of the type of battery chosen to achieve a monitoring system with a minimum size and high efficiency.

In order to characterize the batteries, we have built a device for monitoring their discharge by following the voltage variation until the battery discharge.

The task consists of a system for monitoring and remote transmission of vital parameters, system consisting of a device for measuring the pulse and oxygen concentration in the blood vessels, an EKG device for measuring blood pressure or a GPRS transmission device.

I used two types of batteries for testing: a LiPo battery of 3.7V and a 3.6V NiMH battery. Battery capacity is 4000 mAh.

The block diagram of the battery test device is shown in Figure 1.

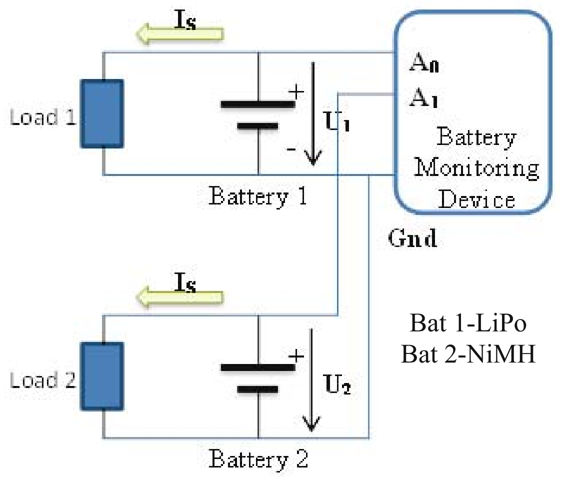

Figure 1. Block diagram

The device for monitoring consists of a data *logger* – that is compatible with the *Arduino Uno Development Board* [11], shown in Figure 2. *Data logger* [12] is fitted with an SD card slot and a card on which you should store the data.

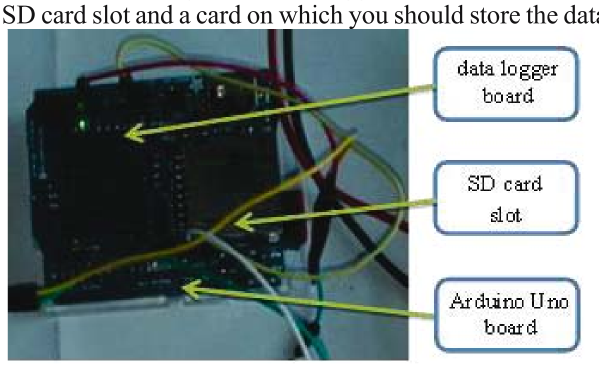

Figure 2. Battery monitoring device with Data logger and Arduino Uno

The conduct of the experiment:

- I realized the testing on two types of batteries 3.6V (LIB) and 3.6V (NiMH)
- a resistive load is used (I = 300mA);
- the monitoring device uses its own power supply;
- the battery monitoring device performs a read of the status voltage at an interval of 3 seconds;
- data is stored on an SD card, and then are transferred to a PC, then processed, and, finally, get data about the effectiveness of the battery type;
- the results obtained are compared - thus establishing the type of the battery efficiency.

The experiment is described as follows:

- carrying out the test device;
- the device controller is programmed for how to read voltage on battery and save data;
- test circuit is carried out based on the block diagram;
- the purchasing system is put into operation;
- the monitoring shall be undertaken until the discharge of batteries;
- stop the acquisition at a battery voltage: U < 0,8V;
- read data from the card and processed with the PC;
- plot graph the change in voltage with load;
- conclusions are drawn from the results obtained.

Discharging chart for the LiPo battery is shown in the Figure 3.

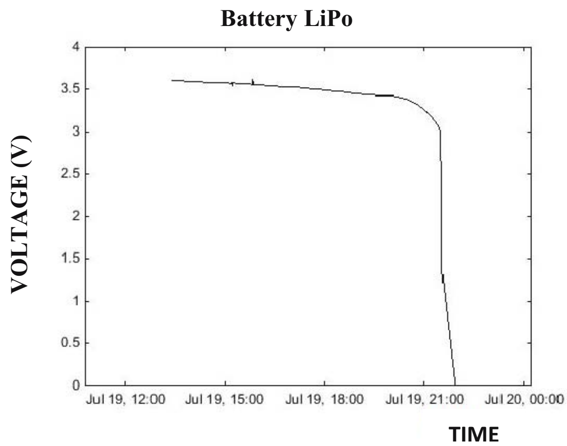

Figure 3. The graph of LiPo battery discharge

Battery power is calculated as:

$$P = U \text{ x } I = \frac{U^2}{R} \tag{1}$$

and the energy is:

$$W = \int_{t_1}^{t_n} P \Delta t \tag{2}$$

$$W = \int_{t_1}^{t_n} U^2 \, \Delta t \, \frac{1}{R} \tag{3}$$

Discharging chart for the NiMH battery is shown in the Figure 4.

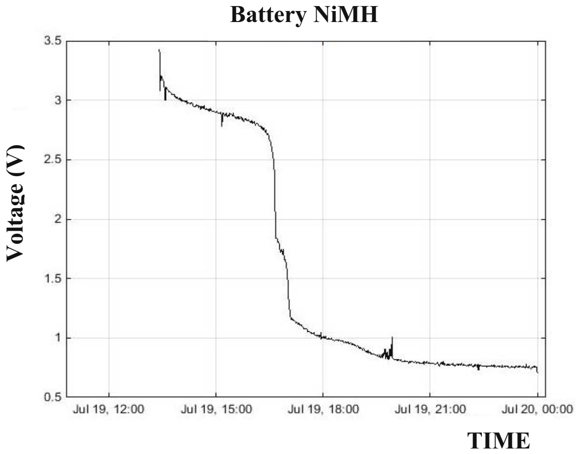

Figure 4. The graph of NiMH battery discharge

4. CONCLUSIONS

According to the discharging graph of the LiPo battery it is found that the period of time when the voltage drops from 3.6V to 2.5V is higher.

In the case of NiMH battery, the time the voltage drops from 3.6V to 2.5V is lower. In terms of power supply voltage, the LiPo battery is more efficient. This type of battery has also the advantage of a smaller gauge that is a strong point for powering electronic equipment, especially portable ones.

The efficiency of a battery is proportional to the ratio of the sum of the squares voltage and battery prices,

$$E = W/p \tag{4}$$

where, p - represents the price of the battery.

Table 1. Experimental data

Battery type	Price/unit [RON]	The discharge time [min]	The energy supplied [unit-watt]	The efficiency
LiPo	65	540	339.14	5.21
NiMH	94	340	145.74	1.55

The energy provided by the LiPo battery was maximum.

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