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INCREASING RELIABILITY AND IMPROVING THE PROCESS OF ACCUMULATOR CHARGING BASED ON THE DEVELOPMENT OF PCGRAPH APPLICATION

Irena Nowotyńska, Andrzej Smykla

***Abstract**: The article presents the software written in Builder C++ that monitors the process of processor impulse charger. Protocol, interface, components used and the future research are presented.*

***Keywords**: PCgraph, developing software, charging process, C++ Builder*

***ACM Classification Keywords**: C.3 SPECIAL-PURPOSE AND APPLICATION-BASED SYSTEMS*

Introduction

The article presents the software written in Builder C++ language that monitors the process of charging through COM port. Pulsar is impulse charger made by Elprog. It is a professional fast impulse charger to charge all kinds of cells available on the market. The product won the prestigious prize “Polish Market” in 2004. Among its qualities are:

1. the speed of charging
2. the reliability of the charger process
3. the regeneration of old cells
4. the monitoring of charging process.

Computer program that read the data directly from charger is a useful tool to analyze the quality of aku pack. The charger system and the graphical interface of PCGraph program is shown in Fig. 1. and Fig. 2.

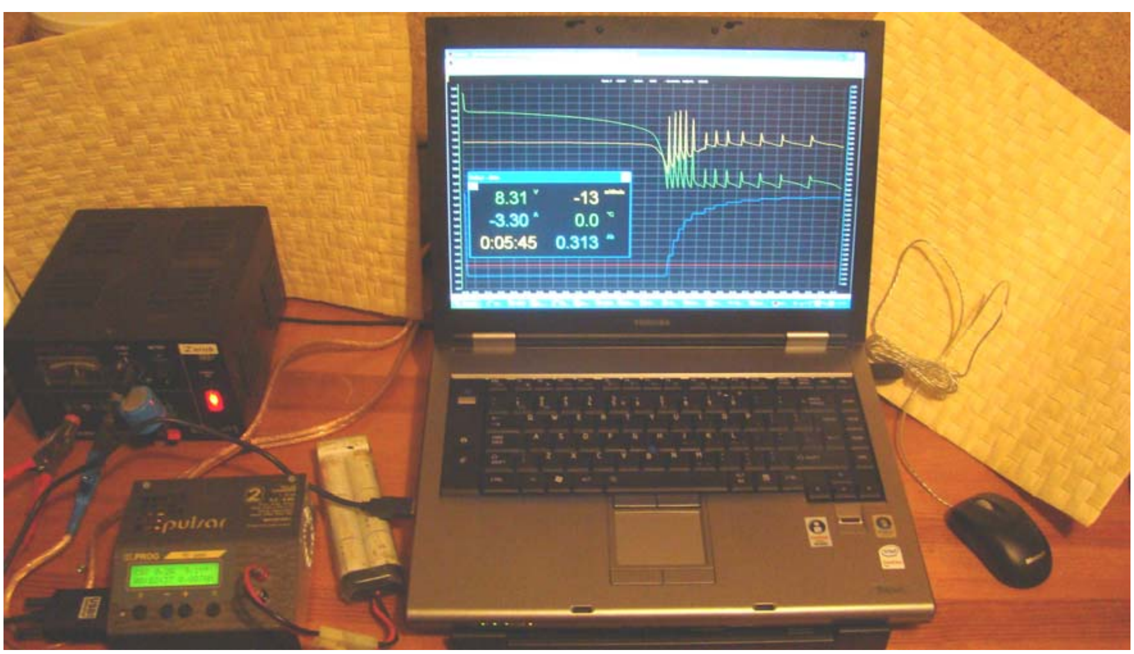


Fig. 1. The charger system during work

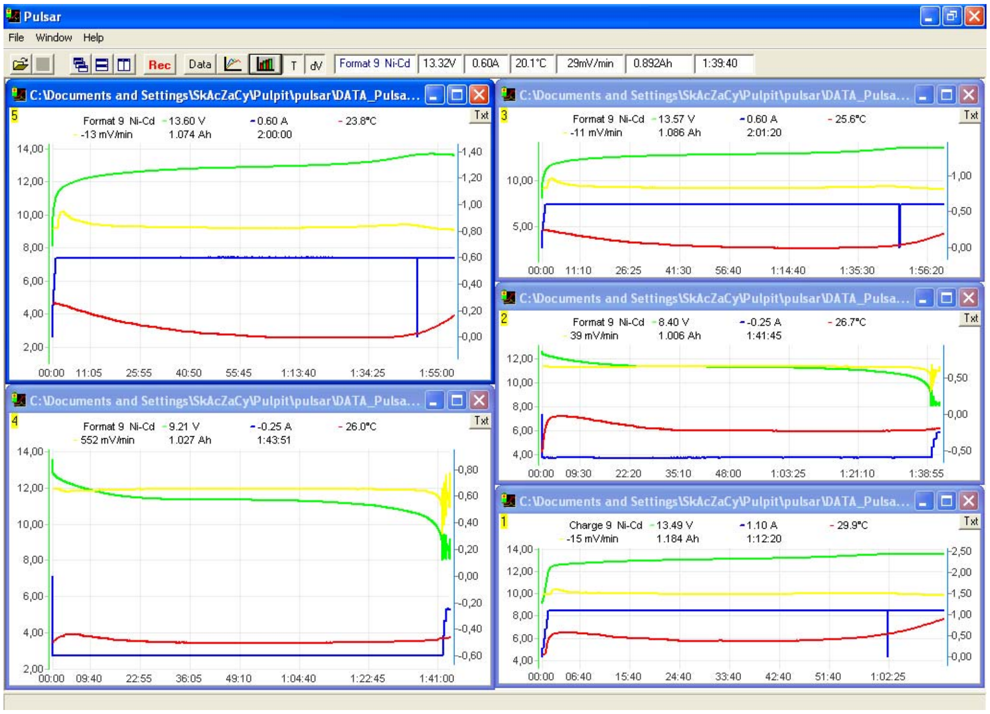


Fig. 2 The graphical interface of PCGraph program (the colors determine: blue – amperes, red – temperature, green – volts, yellow – dV/dt). Figure shows three cycles of charging process and two cycles of discharging

The system is used especially when high reliability is required. The systems work for example in European Space Agency and Polish Polar Station (Spitsbergen).

The program is written in Builder C++ as an MDI application. Components used are presented in Figure 3.

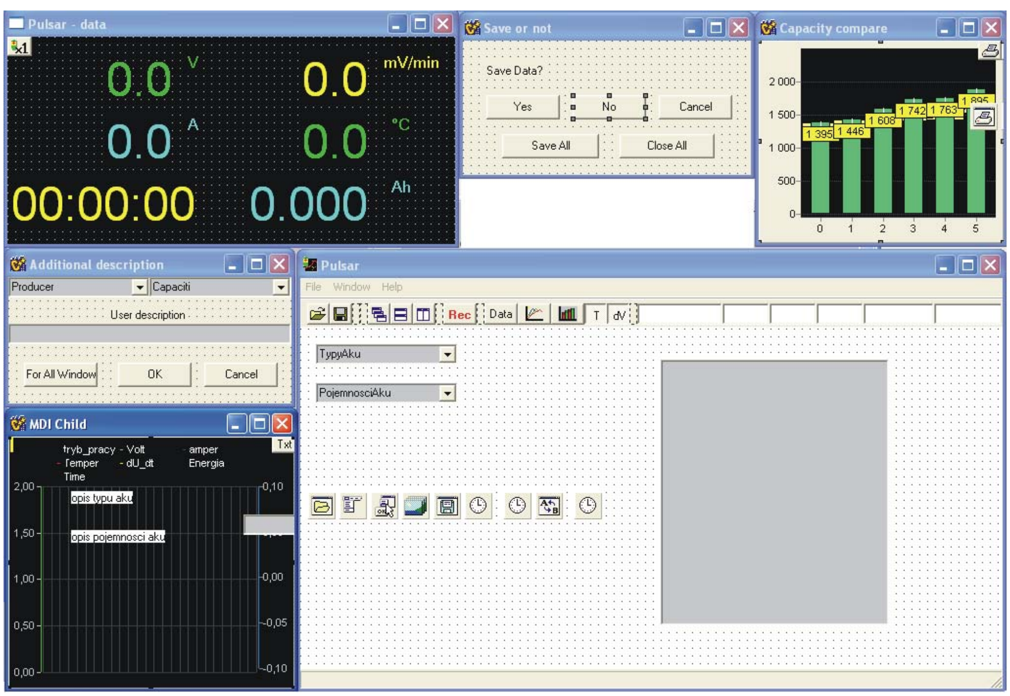


Fig. 3. The view of chosen forms with components used.

The data flows diagram between the most important components are presented in Figure 4.

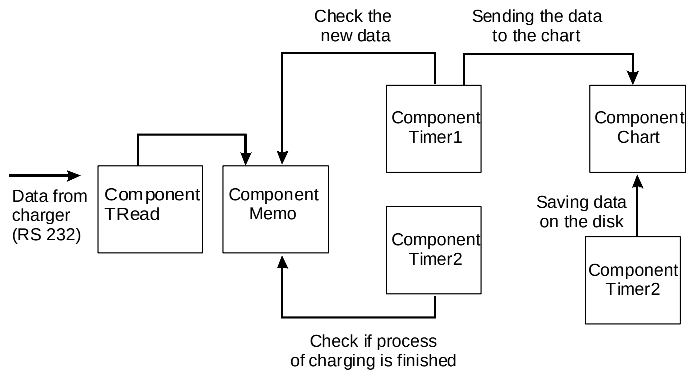


Fig. 4 Data flow diagram of applications.

A serial port is used for communication. The format of protocol (32 bytes long) is presented in Figure 5.

#C	3	5	D	00035,	12029,	+0199,	000,	00001
Begin frame	Number of cells	Cell type	Char. Type	Time[s]	Volts[mV]	Curent[mV]	Temperature[°C]	Energy [mAh]

Fig. 5. The charger communications protocol data format

The type of calls determined the kind of process charging (Table 1).

Table 1

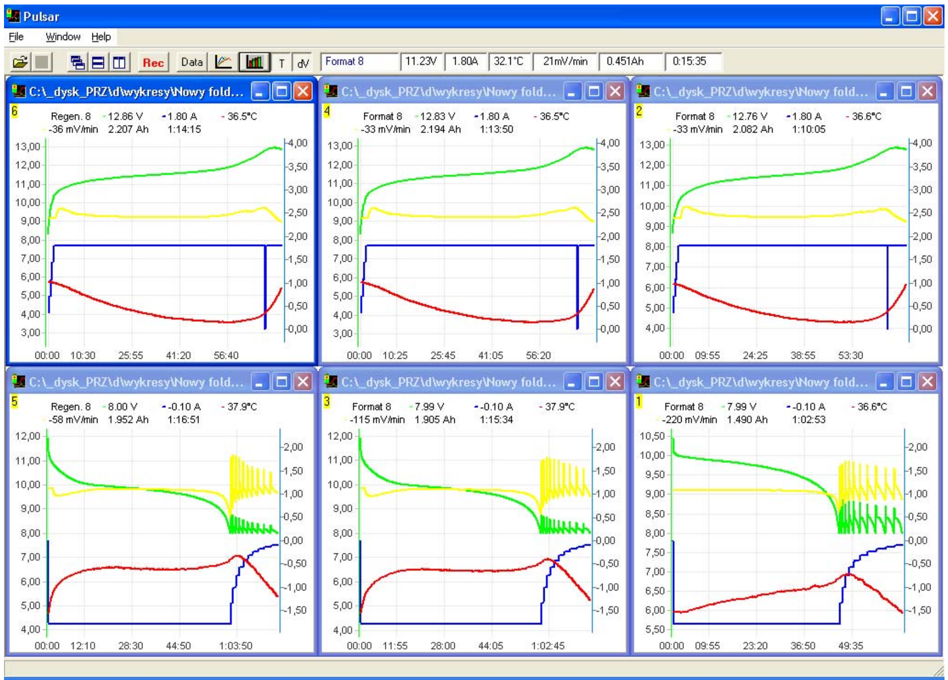
Type of calls	Kind of accumulator
1	Ni-Cd
2	Ni-MH
3	Pb-bat
4	RAM
5	Li-Ion
6	Li-Pol
7	Li-TA
8	Li-S

The charge mode is described with letters – for their meaning see Table 2. The plus and minus sign before the ampere’s value means charging and discharging.

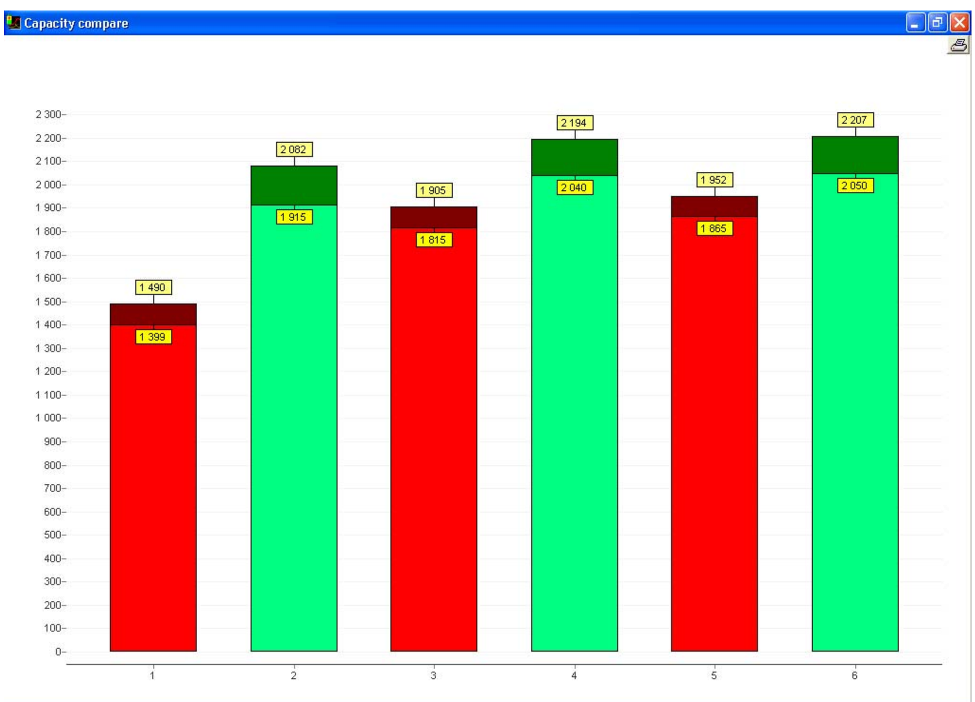
Table 2.

Charge/ Discharge mode	Charge mode
D	Discharge
S	CH. Simple
R	CH. Reflex
P	CH. Pb-bat
L	CH. Lith
C	Regen.
C	Charge
D	Disch
F	Format

The program presented enables the recording of several discharging/recharging cycles and to present the data in graph form. The possibility of such analysis is valuable during the package's regeneration as well as during the determination of its consumption in time (see Figure 6).



a)



b)

Fig. 6. A three-cycle discharging/recharging process in which the capacity of an accumulator package was raised from 1400mAh to 1900 mAh

a) the graph of separate cycles b) the graph comparing capacity

The monitoring program that collects data and presents them in the form of graphs is therefore extremely useful to all that increases the functionality of the charger. The reading and proper interpretation of graphs is possible only after gaining some essential skill by the user which often requires some time and effort.

The analyze of received data

The reading and correct interpretation of charging and discharging process characteristics that are obtained enables us to determine the actual quality of accumulator. However, some experience in reading the characteristics obtained is required.

A correct charging cycle of a twelve-cell NiMH accumulator package is shown in Figure 7.

Fig. 7. A correct charging cycle of a twelve-cell accumulator package.

The list of typical damage of accumulator packages during the charging process is shown in Figures 7-12.

Figure 8a shows how faults of two cells – 1:12 min and 1:45 min - were revealed during the charging process. Data analysis does not enable us to tell which cells are malfunctioning. This information is to be obtained only after measuring the voltage on individual cells.

Fig. 8. The examples of packages of accumulators' with two weaker cells

Figure 9 shows a charging process characteristic that is too flat. The process of voltage rising cannot be observed. Huge differences in charging of individual cells could be the reason – in this case package regeneration might help. The graph might also indicate the wear of the package.

Fig. 9. “Flat” charging characteristic.

Figure 10 shows a case in which faulty cell in the package is revealed (time 0:23:25).

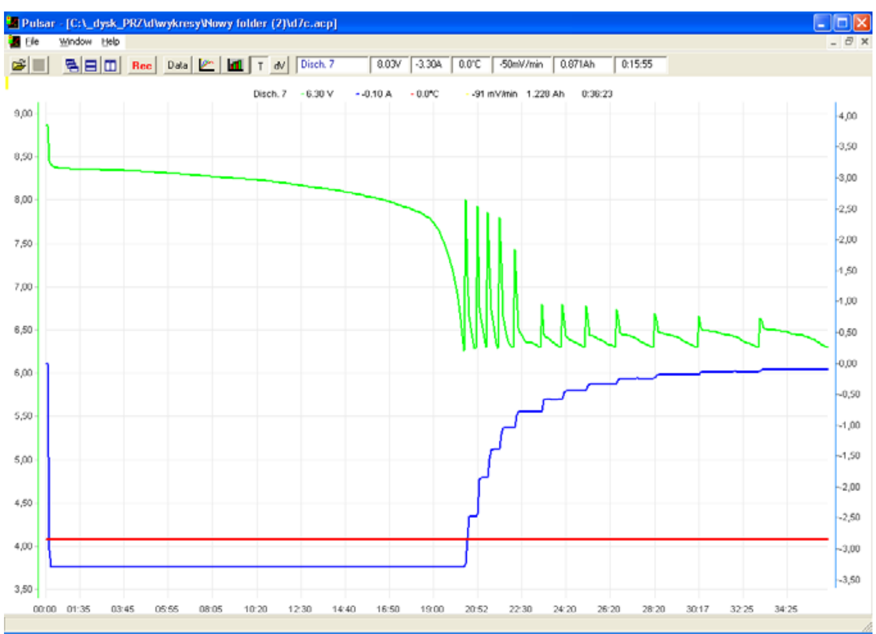


Fig. 10. Charging characteristic indicating the impact of faulty cell.

The process of package discharging with too high internal resistance is shown in figure 11. After 2 minutes 28 seconds the program limited the current (one cell was eliminated). Between 13 and 18 minutes the voltage was partially regenerated on the eliminated cell.

Fig. 11. The partial regeneration of the faulty cell during the discharging process.

Figure 12 shows the effect of package regeneration where one of the cells back to life (6 minutes). The cell was discharged to 0V.

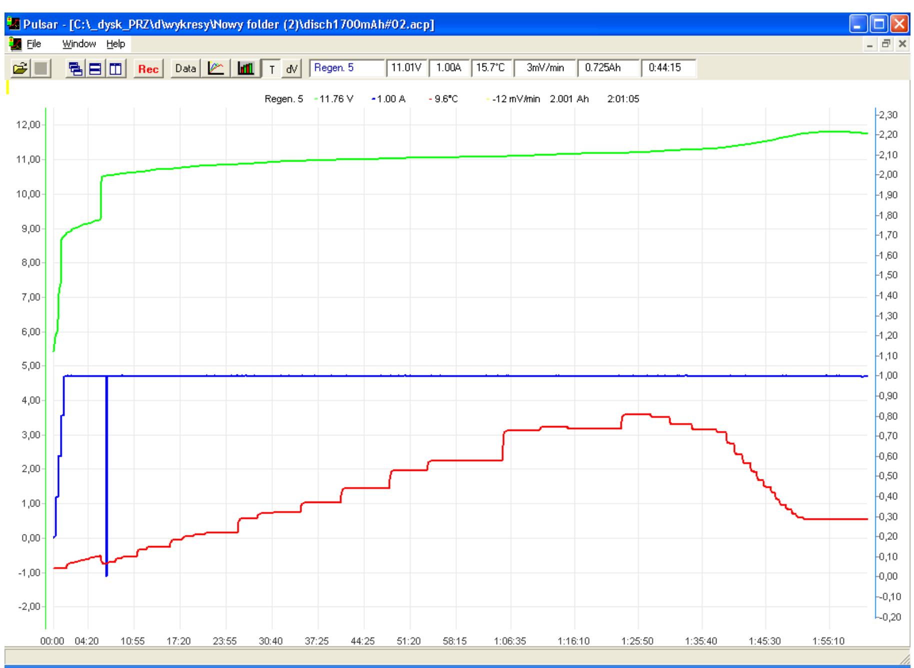


Fig. 12. The charging process of a package with one totally discharged cell.

The next figure (Fig. 13) shows a worn-up package (a case analogical to Fig. 9). The voltage during the charging process increased only a little. However, “Inflex” was correctly revealed. Inflex is a moment in the charging process when a significant temperature rise of the charged accumulator begins. The detection of this point enables us to finish the charging process and therefore the accumulator packages could be usable for a longer time period. The Inflex detection is marked on the voltage graph by a vertical line. At present there is a very small amount of this kind of equipment available on the market. Also, Figure 13 does not depict “Delta Peak” – a point of abrupt voltage change during the charging process – which indicates a significant exploitation of the package.

Fig. 13. The charging process of exploited package.

An example of an unsuccessful attempt at package regeneration is shown in Figure 14. The cycle consisted of two accumulator charging and discharging processes. No improvement in the cell’s parameters was observed. The graph indicates the exploitation of the package.

Fig. 14. An unsuccessful attempt at package regeneration.

A successful attempt at package regeneration was shown in Figure 6.

In case shown in Figure 6 the effective accumulator capacity increased from 1490 mAh to 1952 mAh (about 50%). This information could be gained from the comparative column graphs (Fig. 6b.). In this case the package efficiency was regained in almost 100%.

An ideal charging process is presented in Figure 15 where a correctly revealed Inflex and the end of the charging process at the point of package's temperature rise are shown.

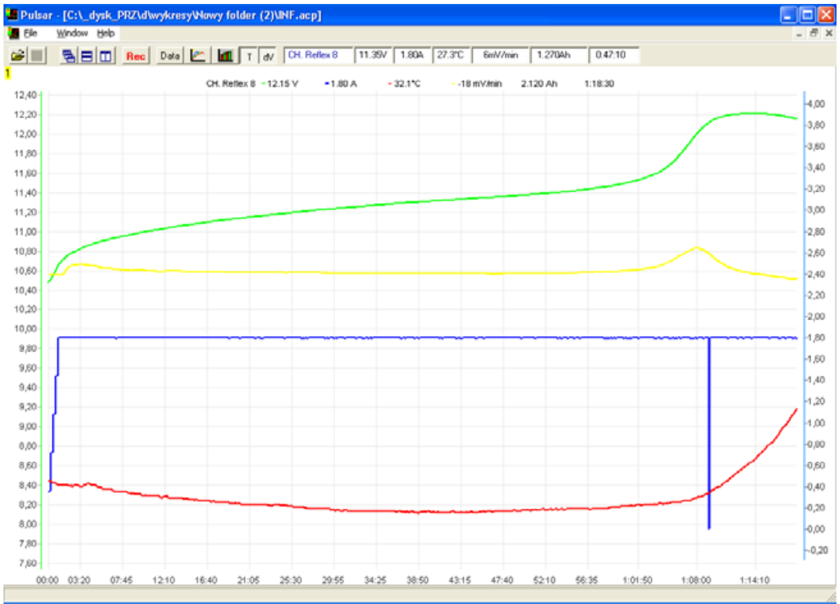


Fig. 15. A correct charging process.

Figure 16 shows a case of self-regeneration of a package during the charging process. After 1 hour, when the current and voltage were limited, the voltage of batter rises. Such situations might happen if a package had not been used for a long time.

Fig. 16. Self-regeneration of a package during the charging process.

Figure 17 depicts a potentially dangerous situation. Data Peak and Inflex were not detected ant the temperature of the accumulator rose. If the package was charged with a big current an inflammation or even an explosion of the package might occur.

Fig. 17. A package reacting to charging not with a voltage rise but with a temperature increase. A potentially dangerous situation.

Equalization of Li-xxx cells

At present lithium cells are more commonly used. Long life-span of this kind of power sources is possible in the case of correct charging of individual cells in the package. It is important that every cell in the package was charged exactly to a certain characteristic voltage. Taking the whole package consisting of several cells into consideration, the entire voltage equals the sum of voltages on individual cells:

$$V_{package}=V_{1\ cell}+V_{2\ cell}+\ldots+V_{N\ cell}$$

The level of package charging is regulated in most chargers in order to protect the unit from overcharging. However, if one of the cells is undercharged, the others take some part of energy and its voltage level is higher. Protection against incomplete charging can be used that partially protects the unit from overcharging. For example, for cells of LiPol type the maximum charging level is set to 4,15V instead of 4,2V. However, with too huge differences in charging levels of individual cells it is only a partial solution. This approach is especially dangerous for cells of LiPol type where overcharging literally causes the danger of package explosion. Therefore, in these cases it seems necessary to use packages leveling devices – balancers. Each cell is then plugged to a unit which brings the individual voltage levels to one level. It is often accomplished by charging the specific cell with a system dissipating the energy in the form of heat. A scheme of such situation is presented in Figure 18.

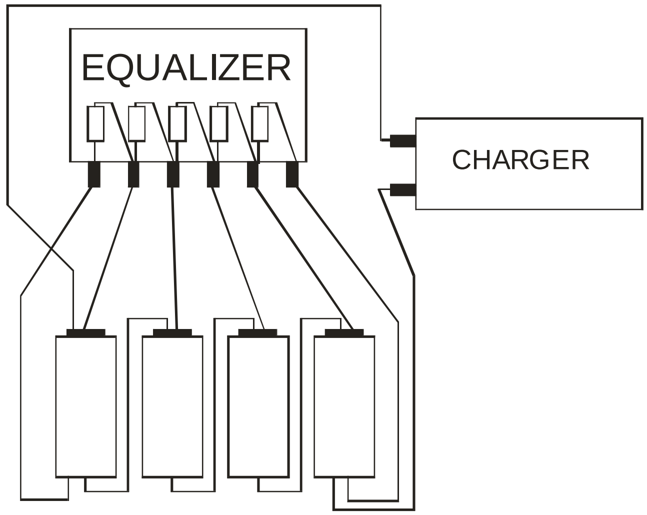


Fig. 18. A scheme of a system balancing the package with simultaneous charging.

Equalizers currently produced by Elprog company are shown in Figure 19.

Fig. 19. Two types of equalizers produced in Elprog company.

As in the case of a charger, both devices provide record and data analysis by a computer system. PCGraph software was adopted to work with these devices. The main window of the program is shown in Figure 20.

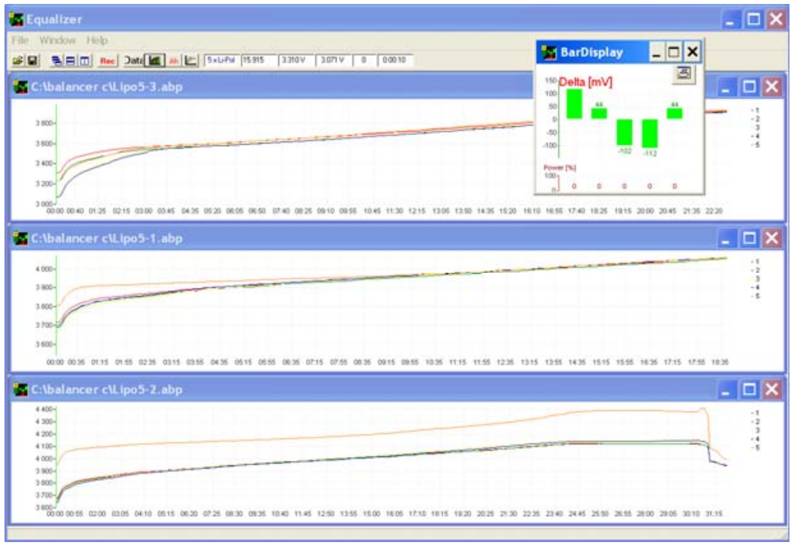


Fig. 20. The PCGraph program - version for EQUALIZER during work.

BarDisplay window seen in the right angle of Figure 20 allows the preview of momentary values of voltage differences on individual cells. As in the case of a charger, the software was written with the use of C++ Builder. A basic unit of components is shown in Figure 21.

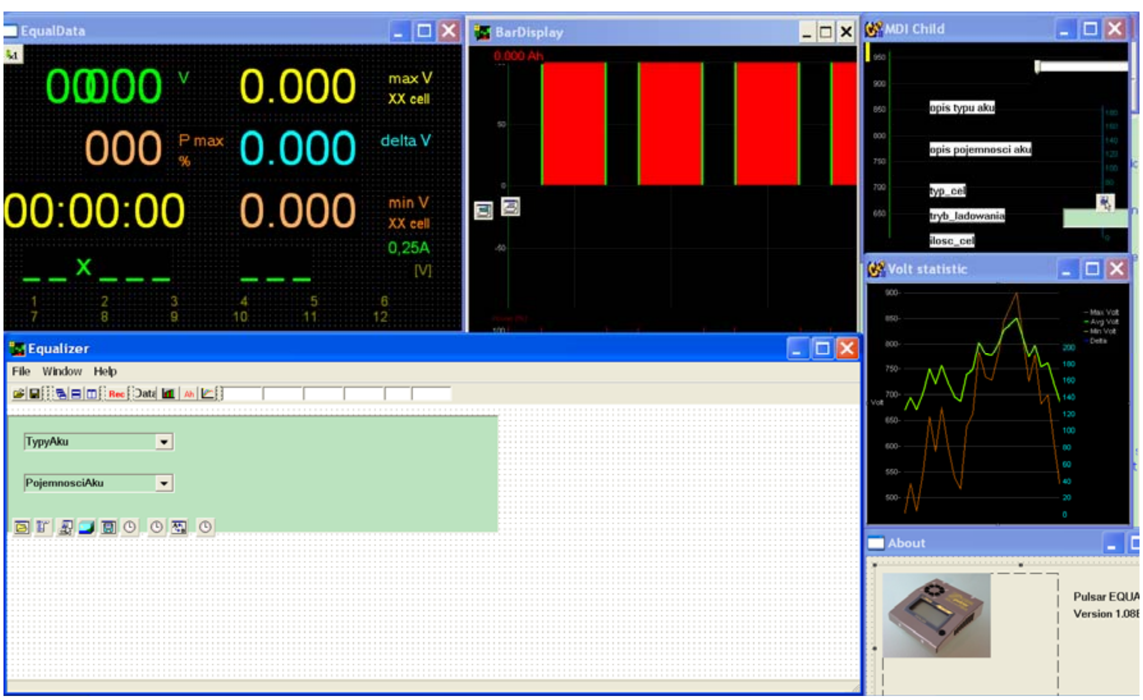


Fig. 21. A basic unit of components of application building in the EQUALIZER version.

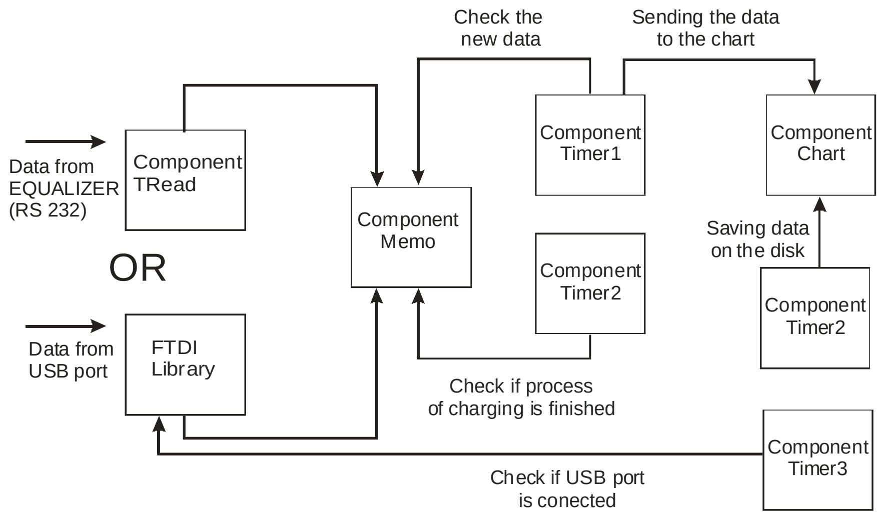


Fig. 22 Data flow diagram of applications.

FTDI library has a set of functions to connect a PC computer with an USB port through an FTDI chip. The set of functions of the chip support is delivered by the producer in the form of DLL library. The format of protocol (80 bytes long) is presented in Figure 23.

#	A	B	C	D	Volt1,	Adjustment1,	Volt2,	Adjustment2,	...,	Volt12,	Adjustment12

Rys 23 The format of protocol for equalizer device

The meaning of fields:

\# - begin frame

A,B,C,D - 4 char

A - mode ASCII

t - test

e - equal

f - fast

B - 1-12 - number of cells HEX

C - 5-7 - type of cell HEX

5 – LiIon

6 – LiPol

7 – LiPh (Fe)

D - reserve {now „B" char is sending}

[Volt] - {0000} 4 char ASCII [mV]

[Adjustment] {0} one char from 0 to 10 in ASCII {0,1, .. 9,:}

[end transmision] -{0D 0A} 2 chars HEX

The data transmission is sent every 5 seconds.

A leveling of package session is presented in Figure 24. The voltage of the whole unit rises which means that a charger was also plugged during the leveling process. There is a possibility of using the equalizer without package charging. The device in this mode is powered by the leveled package so the entire voltage is going to decrease. The big black window shows the read values characteristic for the process. BarDisplay window presents the momentary charging of individual cells (depending on the location of the cursor on the graph). The package shown in Figure 24 was successfully leveled. The values set on individual cells differ no more than 1mV at the end of the process.

Fig. 24. The correct cycle of package leveling.

The current research

Research on the process of creation the expert system that would make reading graphs not essential for the user is being conducted. Initial analyses using the artificial neural network were satisfactory. The network (for the scheme see Figure 25) was prepared as an expert system stating whether the discharging process of an accumulator package finished successfully.

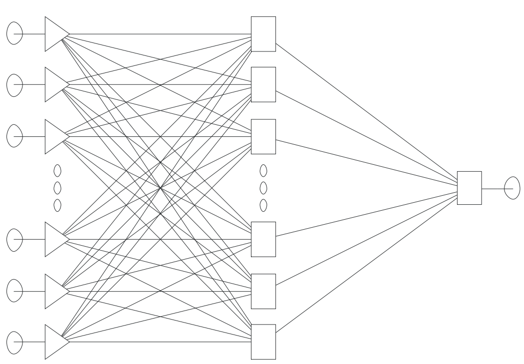


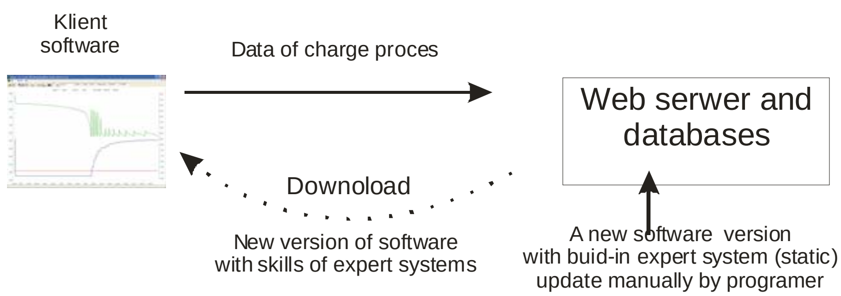
Fig. 25. The scheme of neural network used to identify the fault of accumulator packages.

The data received during the charging process was normalized in table of volting level [U_1,U_2,..,U_n]. The output vector consisted of two elements (the correct package and the wrong package). Coincidence of the network's learning process was observed during the experiment. The modeling of neural network was made in STATISTICA NEURAL NETWORKS system. At this stage collecting more actual data including information about the charging process is crucial. In order to achieve these purposes the current program version includes the record of extra information about the package.

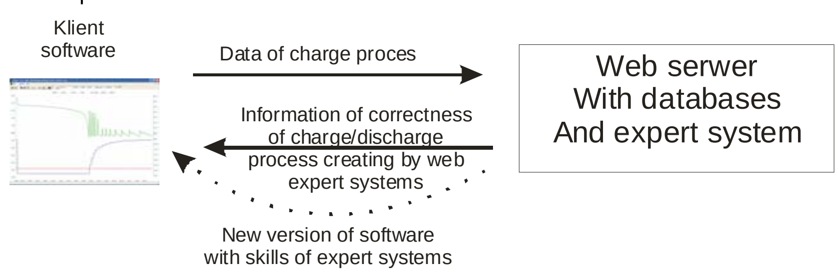
The future

It is probable that the next program version would enable sending the collected characteristics directly to the network server that contains a database. Building an internet server including the expert system is another aim that should be possible to achieve. It would be attainable for the user to check whether their package is correct using the current knowledge of server's expert system and the data could increase sources available. Several possible scenarios of development are shown in Figure 26.

a) Next version of software



b) Possibility of development



c) Future software bases on agent oriented technology.

Fig. 26. The strategy of development of the software presented

The possibility of building evaluation system that would not only find the package faults but also indicate the type of damage, e.g. damage of a single cell (or a few cells), complete discharging of one cell in the package, wrong charging method used (e.g. Ni-Cd accumulators were charged as Ni-MH), wear–out of the package etc should be examined during future research. The significance of such research is emphasized by the fact that the increase of the number of mobile devices was observed in recent years and therefore there will be more demand for evaluating and repair of accumulator. The charger is also currently utilized by certain services such as police, fire brigades where the reliability of technical devices is of great importance. The use of data-mining for huge amount of data might result in development of routine accumulator exchange or inspection standards. The experiments indicate that the chargers delivered with the equipment often cannot make full use of the device. Also they can damage the accumulator packages even though they were destined for the concrete type of equipment as it often happens in different kinds of inexpensive mobile tools. The user exchanges the devices or accumulator packed which causes the increase of their number on garbage dumps and causes the pollution of environment. Therefore, the conduction of this research and further development of software presented seems to be appropriate.

Conclusion

1. The use of application to analyze the charger mode expands the device's possibilities.
2. The analysis of characteristic obtained requires experience in their interpretation.
3. The use of expert system to analyzing chosen signals will be possible in the future.
4. The creation of databases including the characteristics' history during the usage of separate models of accumulators might make it possible to forecast the wear–out of packages. In older to do that an analysis using data-mining should be performed. The current program version includes the mechanism of accumulator description suitable for such research.

The creation of internet service collecting data from the user that might be automatically integrated with the program for expert system learning and data-mining seems appropriate.

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