

Computer controlled testing of batteries

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APPLICATION

COMPUTER CONTROLLED TESTING OF BATTERIES

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Abstract—This paper describes a computer controlled testing device for experimental batteries. The hardware consists of an IBM compatible personal computer and a data acquisition and control interface with additional relay and multiplexer circuits. The software package is written in Turbo-Pascal.

The system is capable of cycling several batteries simultaneously. Charging and discharging of the batteries is controlled by preset cut off voltages and preset maximum charge times. Several parameters which give information about the batteries under test are recorded. Measurements are displayed in real time on the display.

The main advantages of the system are: low price, easy to modify and high accuracy and reliability of the measurements.

INTRODUCTION

Equipment for automatic testing of batteries has been commercially available for many years. However, these systems are designed mainly for large scale cycle-life testing. If complicated test programs must be carried out, expensive equipment is required; moreover, such equipment is not always available. The system described in this paper is very flexible and was built and designed in our laboratory. Almost any user specification can easily be implemented. Although a low price was one of the aims, no concessions were made regarding the reliability and quality of the measurements.

The total price, without the personal computer, will be approx. 2500 Dutch guilders.

REQUIREMENTS

The aim was to study the behaviour of the zinc electrode in nickel oxide-zinc secondary batteries. In these experiments three reference electrodes (Hg/HgO) were inserted at different places near the zinc electrode. The equipment therefore should be able to record the overall cell voltage and the potentials of the three reference electrodes. The use of reference electrodes necessitates differential and high impedance inputs.

The detection of the end of charging and discharging is to be determined by preset limits of the overall cell voltage and the elapsed charge time. If required, the potentials of the reference electrodes can also be used as a charge/discharge limit.

Efficient testing is only possible when several batteries are cycled simultaneously.

Charge and discharge curves of batteries show rapid voltage changes at the start and end of the (dis)charge process. Accurate measurement of such voltage changes should be possible.

The data of the measurements should be displayed on an alphanumeric display or a graphical display, allowing visual control of the tests.

The software should make use of several cycling parameters and provide extensive data storage on disk, allowing future data processing. Also the software should be structured which would allow easy modification.

SPECIFICATIONS

Since the data acquisition is the fundamental part of the equipment and special specifications were needed regarding connection of reference electrodes, a high quality analog to digital converter was essential. This led to the choice of the IBM DACA (Data Acquisition and Control Adapter). The four available A/D converters have high accuracy (12 bit conversion on 10 V full scale, approx. 2.5 mV resolution), differential inputs and high input impedance ($\geq 10 \text{ M}\Omega$), thus allowing direct connection of the required reference electrodes.

Charge and discharge current, supplied by an external power supply, is set manually. In this setup the maximum current is limited by the maximum allowed current of the relays connected to the DACA card.

The DACA card does not reset after a power drop or a computer failure; this leads to "hanging" relays, and could result in overloading or too deep discharging of the batteries. Therefore, a circuit is introduced to prevent damage of the batteries. When a failure is detected, this circuit disconnects the batteries from the DACA card until the equipment

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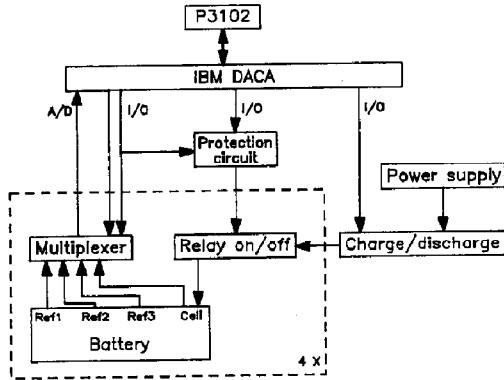


Fig. 1. Basic setup for computer controlled testing of batteries. Only one battery is shown.

is re-initialized (thus preventing damage of the batteries).

After each cycle the measurements are stored on disk (in an ASCII format). In addition to the measured cell voltage and reference electrode potentials, the following parameters are filed separately: charge and discharge time, coulombic efficiency, relative capacity (i.e. the actual discharge time divided by the preset maximum charge time), energy dissipated during charge and discharge, average potential during charge and discharge, the potential at the end of the charge period and pause period. These parameters can be plotted after finishing all the cycles.

HARDWARE

The hardware consists of an IBM compatible personal computer (Philips P3102), an IBM DACA interface and a relay and multiplexer circuit connected to IBM DACA.

The basic setup is shown in Fig. 1.

The batteries are connected in series and are taken out of the circuit with a relay controlled by the computer. The direction of the current is reversed (i.e. charge or discharge) with another relay. In case of discharging an extra resistor is put in series with the batteries thus allowing the power supply to maintain the desired discharge current.

Since 16 differential input channels are needed, every A/D converter of the DACA is multiplexed to four input channels with a multiplexer chip (MPC4D Burr Brown).

During normal operation the digital I/O lines are activated at least every 5 min (maximum time for a graphics dump on the printer). If the protection circuit has not detected any access of the I/O lines during 10 min, a computer failure or a power drop is assumed. The batteries are then taken out of the (dis)charge circuit. On the frontpanel a LED will start to blink.

The complete circuit diagram is given in Fig. 2.

SOFTWARE

In Figs 3, 4 and 5 the layouts of the input screen, status screen and graphics screen of the program are

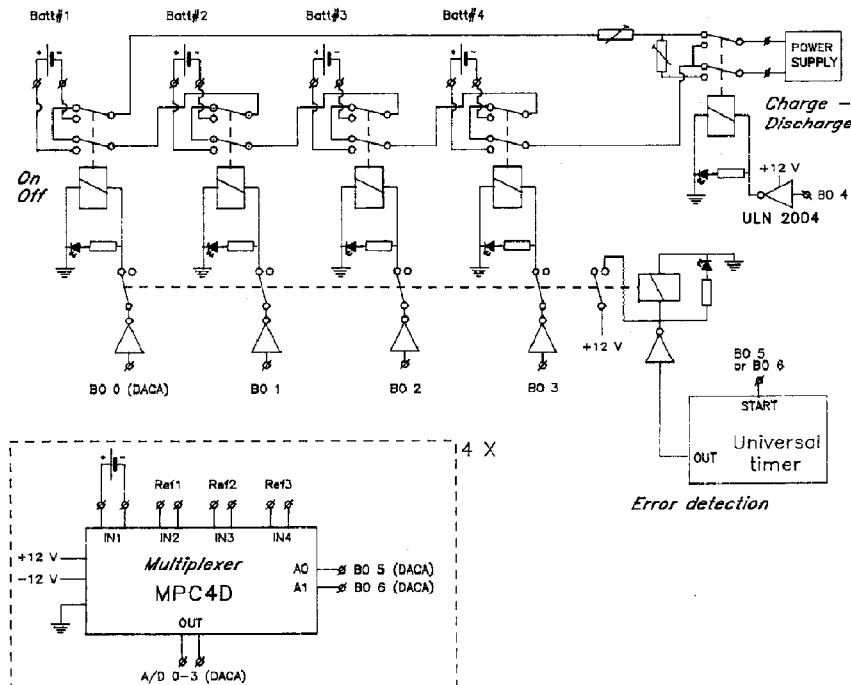


Fig. 2. Circuit diagram of the additional hardware connected to the DACA card.

```

AUTOCYCLER V1.1 (C) TUE/TEE Eindhoven NL
Number of batteries connected : 4
Cyclenr : 1
Test on cellvoltage : YES
Test on Reftpotential : NO
Name battery #1 : Batt#1
Name battery #2 : Batt#2
Name battery #3 : Batt#3
Name battery #4 : Batt#4

Initial : CHARGING
TimeInterval : 6 [Min]
PotentialInterval : 15.00 [mV]
Pause : 15.00 [Min]
Maximum charging Time : 150.00 [Min]
DisplayMode : TEXT

Charge / Discharge Limits
      Batt#1      Batt#2      Batt#3      Batt#4
    Lo  Hi  Lo  Hi  Lo  Hi  Lo  Hi
Cell : 1.00 2.05 1.00 2.05 1.00 2.05 1.00 2.05
Ref1 : 1.00 2.05 1.00 2.05 1.00 2.05 1.00 2.05
    
```

Fig. 3. Example of the screen used for entering the input parameters.

presented. These examples are taken from a test of NiOOH-Zn batteries. A Hg/HgO reference electrode was implemented to measure the potential of the zinc electrode (Ref 1 in the figures).

The software is written in Turbo-Pascal (Borland). It is possible to implement other A/D converters and/or relay cards and, if necessary, to adapt the

software to user specifications. A listing of the program is not given (1600 lines of source code), however diskettes with the described program can be obtained from the author. A simplified flow chart of the program is given in Fig. 6.

A brief description of the used procedures is given next.

		Reading			
		Batt#1	Batt#2	Batt#3	Batt#4
Status	:	ON	ON	ON	ON
Cell	:	1.82	1.80	1.87	1.81
Ref #1	:	1.89	1.83	1.90	1.80
Ref #2	:	1.86	1.83	1.83	1.88
Ref #3	:	1.88	1.82	1.84	1.89

		Sampled			
		Batt#1	Batt#2	Batt#3	Batt#4
Cell	:	1.85	1.87	1.83	1.85
Ref #1	:	1.83	1.84	1.86	1.87
Ref #2	:	1.84	1.81	1.84	1.83
Ref #3	:	1.85	1.83	1.83	1.81
Sample	:	21	20	24	22
C-energy	:	2.2	3.3	4.4	5.5
D-energy	:	6.6	7.7	8.8	9.9

Status	Cycle	Time	ChargeTime	DischargeTime
CHARGE	1	13:17:23	78	

*E Exit 1 2 3 4 PlotMode Graphics Text Last cycle Hardcopy ? Help

Fig. 4. Example of the alphanumeric status screen.

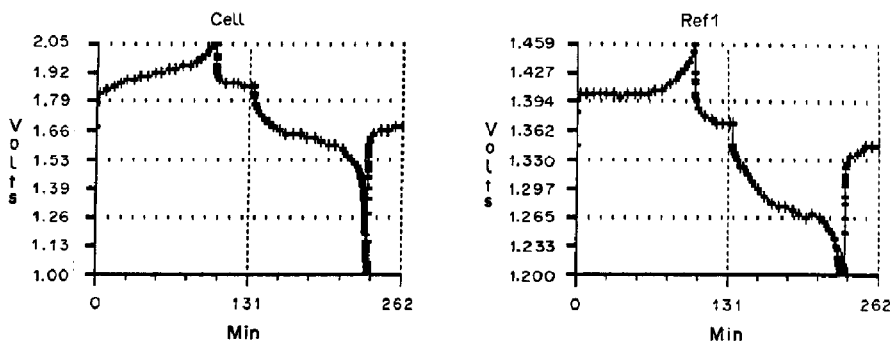


Fig. 5. Example of the graphics screen (Cell and Ref 1).

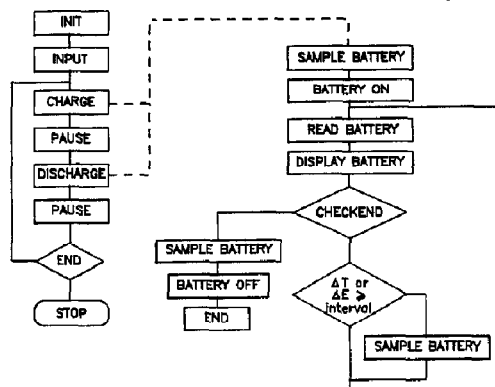


Fig. 6. Simplified flow chart of the program.

Battery on/battery off

These procedures activate the relays which switch the (dis)charge current of the separate batteries on or off.

Read battery

This procedure selects the A/D converter connected to the corresponding battery. Multiplexing this input channel allows the cell voltage and reference potentials to be measured separately.

Sample battery

As mentioned before, the rapid voltage changes should be measured accurately. Therefore, samples are taken on two intervals, viz. after a specified time

or after a specified potential difference relative to the last taken sample.

These intervals are entered when the program starts. Since only a limited amount of samples (256 per input channel) can be stored per cycle, these intervals must be chosen carefully. Combinations which will result in too many samples are not permitted by the program. If, due to unexpected noise, the number of samples exceeds the allowed maximum, the first sampled data will be lost.

Display battery

Depending on the display mode (text or graphics), the measurements are displayed on an alphanumeric or on a graphics screen. Both displays are updated continuously. In the graphical mode only four plots (out of 16 possible plots) can be shown simultaneously. The combination to be displayed can be chosen from the keyboard. The alphanumeric screen displays the following parameters: the actual value of the inputs; the last sample taken; the status of a battery (on or off); the status of the program (charge, discharge, pause or storing data); the actual time; the actual pause, charge or discharge time and the actual dissipated energy during charge and discharge.

Check End

The measured potentials are checked with the preset charge and discharge limits and the preset maximum charging time. If one of these limits is exceeded, the corresponding battery is switched off. If all the connected batteries are switched off, the

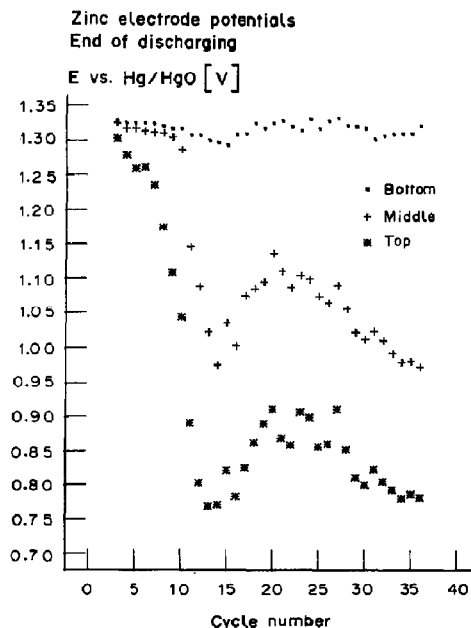
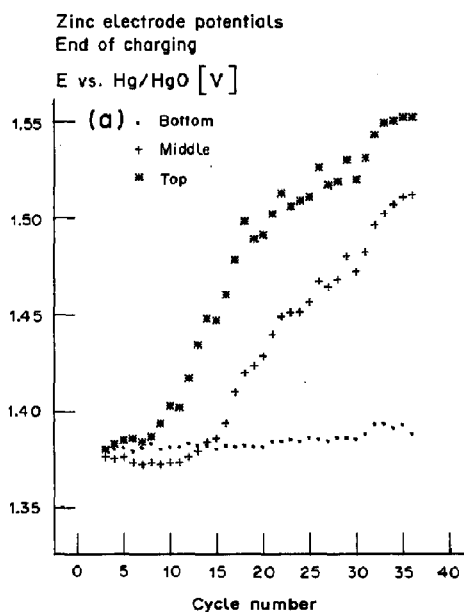


Fig. 7

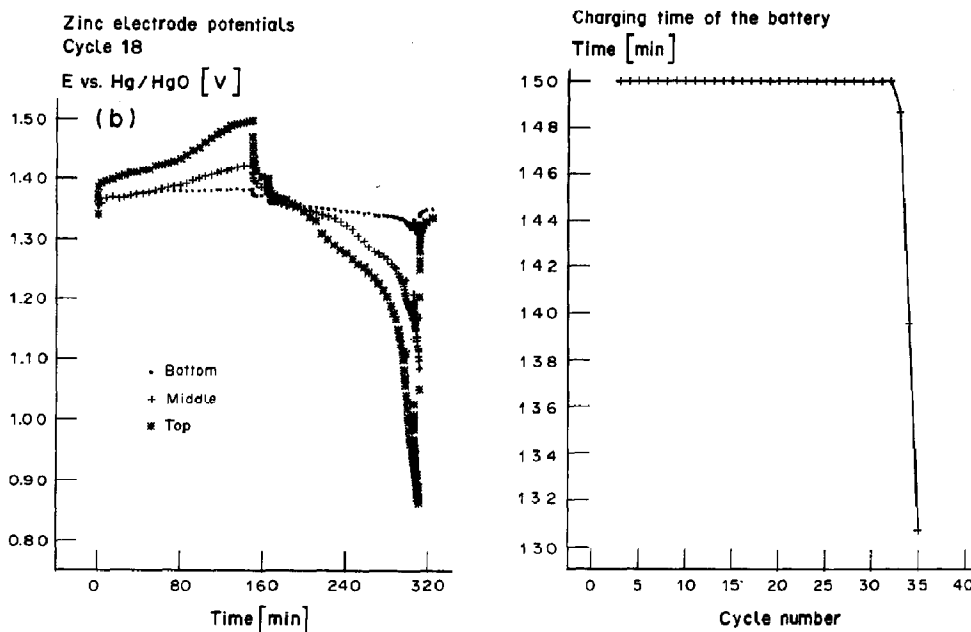


Fig. 7. Examples obtained after processing the stored data from the completed battery test. Plots are shown of (a) the zinc electrode potentials at the end of charging and discharging, and (b) the potentials of the three reference electrodes simultaneously and the charging time during cycling.

program will go to the next cycle section. If the present cycle is finished, the measurements will be filed to disk. If no input was given to stop the program, the next cycle will be started.

EXAMPLE OF DATA PROCESSING

Once the test is completed, the filed measurements can be processed with another program. In Fig. 7 some results of such data processing are presented.

These data are the result of experiments with a NiOOH-Zn battery. Three Hg/HgO reference electrodes monitor the potential of the zinc electrode at different places nearby the zinc electrode.

The program plots various parameters versus cycle number or time. Capacity, coulombic efficiency and the charging time give information about the battery as a whole, whereas the potential of the zinc electrode registers the contribution of the zinc electrode to battery failure. Only the end of charge and end of discharge potential are plotted, because they are the most informative about the state of the battery or zinc electrode.

LIMITATIONS AND OPTIONS

Two minor limitations exist in the present hardware and software which cannot be easily evaded:

Switching between charging and discharging occurs simultaneously for all the connected batteries. In

practice, each battery has a different charge- and discharge-time and so the pause periods can vary for each battery.

Since the program has a limited speed it is impossible to use short (dis)charge times (in the range of seconds). Use of a high speed computer could evade this problem.

Through minor changes in the hardware and software some interesting options can be used:

Instead of the applied reference electrodes, the reference inputs can also be used to measure, for example, temperature and/or pressure changes during the test. These parameters can also be used as (dis)charge limits.

In this setup all batteries will be (dis)charged with the same constant current. Optionally, the charge and discharge current can be computer controlled if a suitable power supply is used. Different or variable charge and discharge currents are then possible.

The maximum number of batteries can be varied. If no reference inputs are required up to 16 batteries can be tested simultaneously. An extra DACA card allows the testing of eight batteries with full use of the software capabilities.

The software allows measurement of changes in the ohmic resistance in the batteries. If the current through the battery is switched off, a sample is taken due to the rapid drop of the voltage. Since the time interval is always the same, the measured potential interval is related to the ohmic drop.