Short Communication

A Low-cost, Computer-aided Electrochemical System for Characterizing Battery Electrodes

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Summary

A low-cost, computer-aided facility to conduct charge/discharge operations on battery electrodes is reported. The facility can also be used for conducting galvanostatic polarization measurements on the electrodes.

Introduction

The conventional mode of data collection and processing required to determine the performance of electrochemical power sources involves regular manual attention and, hence, is tedious. This task can, however, be efficiently handled through microcomputers [1, 2]. In recent years, some computer-aided electrochemical systems have become commercially available but are configurationally complex and expensive. A low-cost, computer-aided electrochemical system for characterizing battery electrodes is reported in this communication. Besides being a facility to conduct charge/discharge operations on the electrodes, the system can also be employed for conducting galvanostatic polarization measurements.

Experimental

Hardware

The hardware of the facility is shown schematically in Fig. 1. It comprises an IBM-PC-compatible analog-to-digital and digital-to-analog converter card (ADDA) with a 12-bit-16-channel analog-to-digital converter (ADC) and a single-channel digital-to-analog converter (DAC) that interfaces the experimental mainframe to an IBM-PC. The DAC makes ±9 V available as analog output during any unipolar/bipolar operation. In order to measure the analog input through the ADC, a floating-input amplifier has been provided with an adjustable-gain potentiometer. The input impedance of the floating-input amplifier is sufficiently high (>10 MΩ) to avoid the electrochemical cells being loaded during the measurements.

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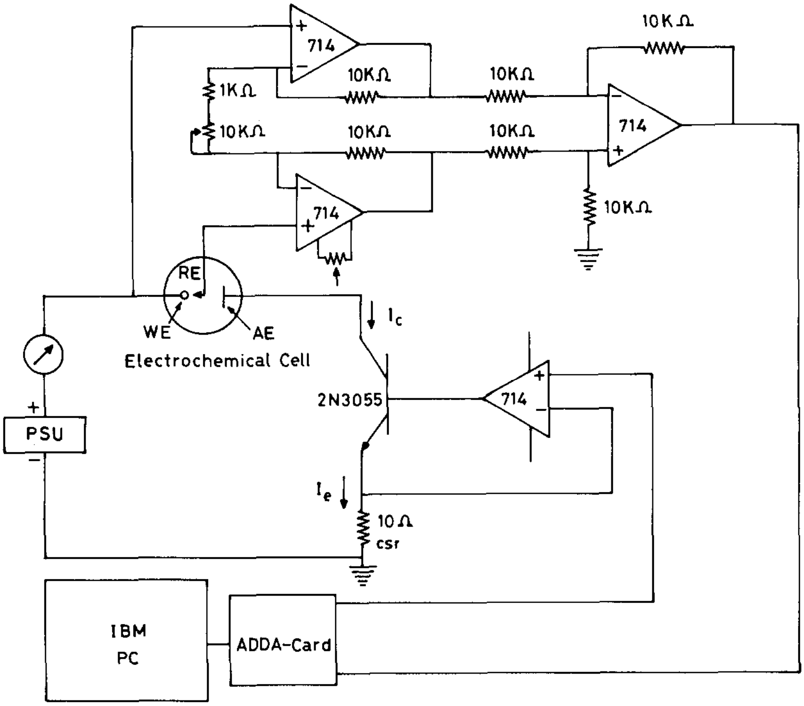
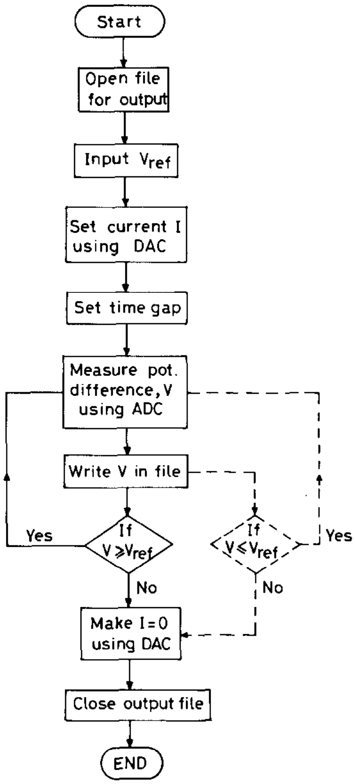


Fig. 1. Schematic representation of computer-aided electrochemical facility; RE, WE and AE are reference, working and auxiliary electrodes of electrochemical cell, respectively.

As the internal resistance of the electrochemical systems varies with the state-of-charge of the electrodes during the charge/discharge operations, an operational-amplifier-based constant-current source has been designed to meet the requirements of the experiments. The emitter current, I_e, of the transistor, is adjusted by the operational amplifier (IC-714) as shown in Fig. 1. The set value of the voltage (V_{set}) in the DAC output is exactly reproduced at the current-sensing resistor (c.s.r.) with the other end of the c.s.r. maintained at zero voltage. The emitter current, I_e, is given as: $I_e = V_{set}/R_{csr}$, where R_{csr} is the resistance associated with the c.s.r.. As $I_e \simeq I_c$ (collector current) in the transistor, the load current on the electrochemical cell is constant and proportional to the set voltage. The IBM-PC drives the hardware to regulate the current at a set value for a desired period through the software described in the following section.

Software

The flowchart for writing the program to conduct charge/discharge operations on the electrodes is given in Fig. 2. The program written in GW-BASIC for discharge operation is given in Appendix A. The processor keeps the current constant and monitors the change in potential with time. The power supply is cut as, and when, the cut-off potential is reached.



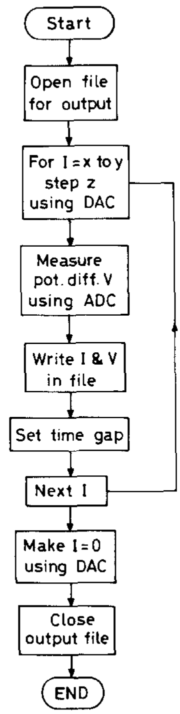


Fig. 2. Flowchart of software for constant-current discharge operation; broken lines correspond to charge operation.

Fig. 3. Flowchart of software for galvanostatic polarization.

The flowchart for writing the program to conduct galvanostatic (anodic/cathodic) polarization experiments is shown in Fig. 3 and the relevant program is given in Appendix B. During this experiment, the current is monitored through the DAC and the electrode potential measured with the ADC as a function of time. The current is varied in certain defined steps after the electrode under polarization achieves a steady-state potential value.

Electrochemical characterization of electrodes

The facility has been successfully tested for conducting charge/discharge operations on an iron electrode in a nickel/iron cell. The electrode potential, V, is measured against an Hg/HgO, OH^- electrode at one minute intervals and stored in an output file. The acquired data during the electrode discharge process is presented in Fig. 4.

The facility has also been tested for galvanostatic polarization of the iron electrode in alkaline medium, both in the anodic and cathodic modes, by setting the time gap between each current step as 5 min. The potential values

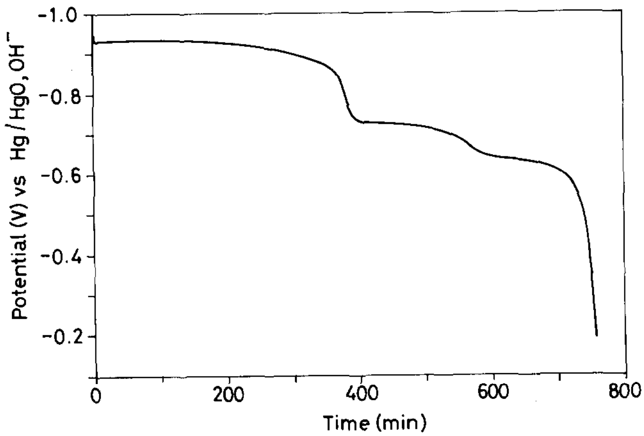


Fig. 4. Characteristic discharge curve for alkaline-porous iron electrode.

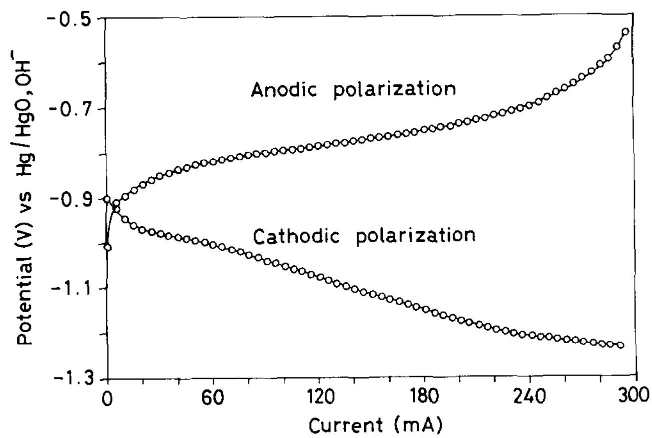


Fig. 5. Anodic and cathodic polarization curves for alkaline-porous iron electrode.

are found to attain a steady state within this period. The acquired data are shown in Fig. 5. The quality of the pertinent data is obviously high.

Acknowledgements

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References

1 W. G. Marshall, R. Leek, M. J. Pilkington and N. A. Hampson, *J. Power Sources, 16* (1985) 119.

2 M. V. Ananth, B. Manivannan and K. Dakshinamurthy, *B. Electrochem.*, *4* (1988) 927.

Appendix A

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10 'SOFTWARE FOR CONSTANT CURRENT DISCHARGE USING ADDA CARD
20 KEY OFF:CLS:PORT = 760
30 INPUT "<ENTER FILE NAME FOR OUTPUT>", FILE$
40 OPEN "O", #1, FILE$
50 PRINT
60 INPUT "<ENTER CUT-OFF POTENTIAL VALUE IN VOLTS>";VA
70 CLS
80 K=0:I=100
90 OUT PORT+6, I
100 OUT PORT+7, 1
110 PRINT "*** CONSTANT CURRENT DISCHARGE EXPERIMENT IS IN PROGRESS***"
120 PRINT
130 LOCATE 3, 22:PRINT "CURRENT = "I*.8317" mA"
140 PRINT :PRINT
150 PRINT "No.", "POTENTIAL V"
160 PRINT
170 CHANNEL=0
180 GOSUB 290
190 E=INP(PORT+2)
200 C=INP(PORT+1)
210 D=(E-16*(INT(E/16)))*256+C
220 V=D/425
230 PRINT #1, K; V
240 PRINT K, V
250 FOR T=1 TO 125000! :NEXT
260 IF V <=VA THEN 340
270 K=K+1
280 GOTO 170
290 OUT PORT+3,0
300 OUT PORT+0, CHANNEL
310 FOR B=1 TO 7:A=INP(PORT+4):NEXT B
320 FOR B=1 TO 7:A=INP(PORT+5):NEXT B
330 RETURN
340 OUT PORT+6, 0:OUT PORT+7,0
350 PRINT: PRINT "CONSTANT CURRENT DISCHARGE EXPERIMENT IS OVER"
360 BEEP: END
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Appendix B

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 10 ‘SOFTWARE FOR GALVANOSTATIC POLARIZATION USING
    ADDA CARD
 20 KEY OFF:CLS:PORT=760
 30 INPUT “<ENTER FILE NAME FOR OUTPUT>”, FILE$
 40 OPEN “O”, #1, FILE$
 50 PRINT:PRINT:INPUT “ENTER MAX CURRENT IN mA”, REF
 60 CLS
 70 PRINT “*** GALVANOSTATIC POLARIZATION EXPERIMENT
    IS IN PROGRESS***”
 80 PRINT:PRINT
 90 PRINT “CURRENT mA”, “POTENTIAL V”
100 PRINT
110 I=0:L=0
120 OUT PORT+6,I
130 OUT PORT+7,L
140 CHANNEL=0
150 GOSUB 260
160 E=INP(PORT+2)
170 C=INP(PORT+1)
180 D=(E-16*(INT(E/16)))*256+C
190 V = D/425
200 PRINT #1, (I*.235 + L*59);V
210 IF I>=255 THEN I=0:L=L+1
220 PRINT (I*.235 +L*59), V
230 I=I+10
240 FOR T=1 TO 5*125000! :NEXT
250 GOTO 310
260 OUT PORT+3,0
270 OUT PORT+0, CHANNEL
280 FOR B=1 TO 7:A=INP(PORT+4):NEXT B
290 FOR B=1 TO 7:A=INP(PORT+5):NEXT B
300 RETURN
310 IF (I*.235 L*59)<=REF THEN 120
320 OUT PORT+6,0:OUT PORT+7,0
330 PRINT: PRINT “GALVANOSTATIC POLARIZATION EXPERIMENT
    IS OVER”
340 BEEP: END
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