Lithium-ion Battery Charge Methodologies Observed with Portable Electronic Equipment

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The 2009 Space Power Workshop
April 21-23, 2008

Introduction

- Commercial lithium-ion batteries in portable electronic equipment has been used by NASA for space applications since 1999.
- First battery that was certified for flight and flown for Shuttle use was the Canon BP 927 (2.7 Ah) battery pack.
- Since then, numerous portable equipment with li-ion batteries have been certified and flown and remain on-orbit for crew usage.
  - Laptops (two generations with third one being worked on now)
  - Camcorder
  - Camera
  - PDA – 2 versions (second one being li-ion polymer cells)
  - Satelite Phone
- Due to expense and time, certified batteries are used with different equipment with the help of adapters or by working with the manufacturer of the equipment to build the appropriate battery compartment and connector.
- Certified and dedicated chargers are available on Shuttle and on the ISS for safe charging.

Contributors

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- Former Battery Group Members
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  - Bob Bragg
  - Claude Wooten

Canon Camcorder Battery (BP 927 and BP 930)

Chargers:
Canon CA 900 or
CA 910.

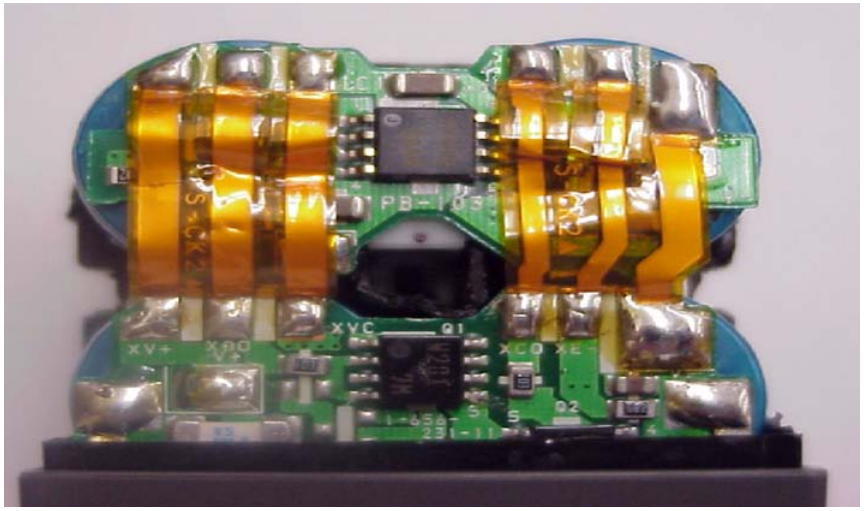
Weight: 188.14 g

Dimensions: 1.52”X 2.76”X 1.50”

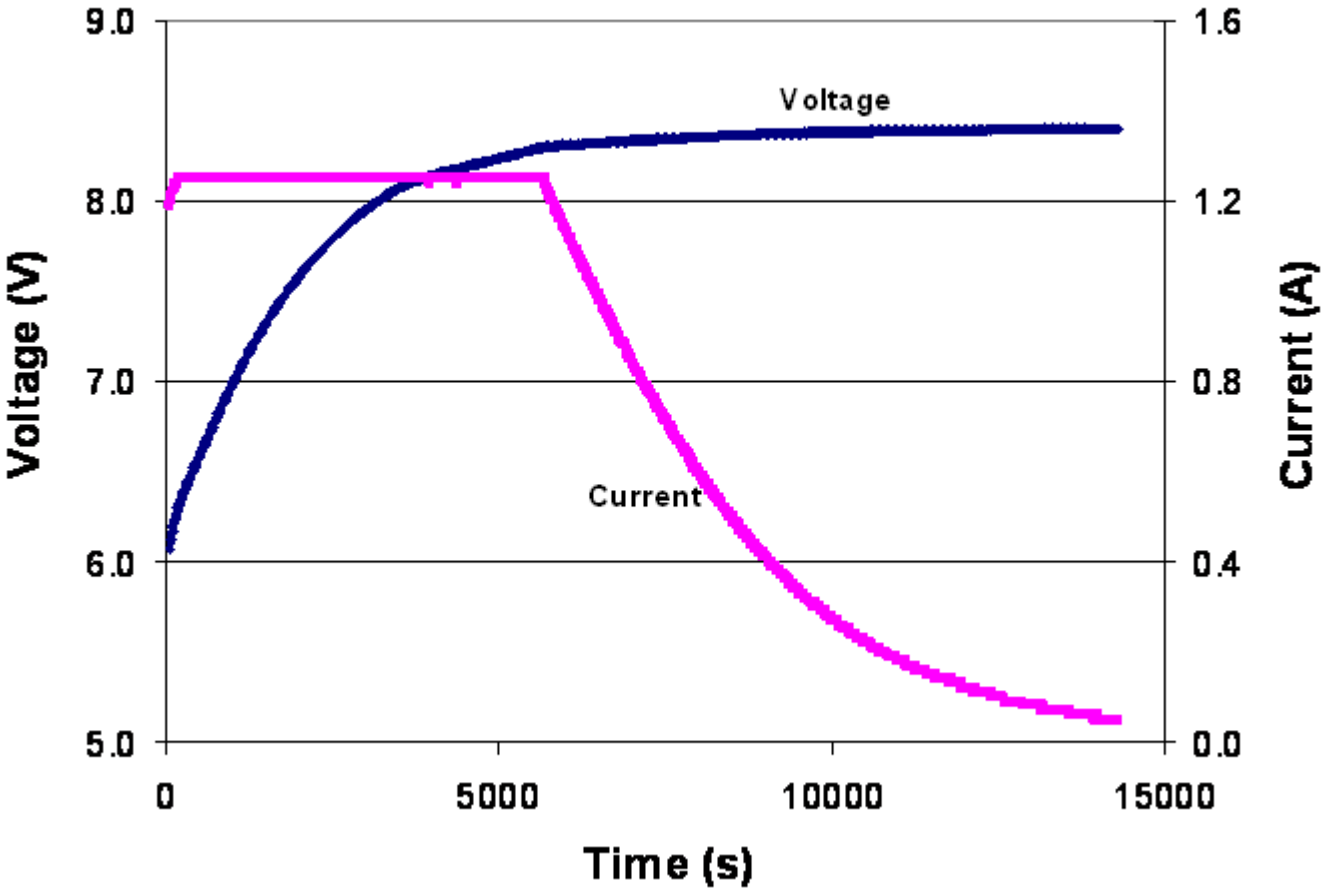
Voltage: 7.2 V

Capacity: 3.0 Ah

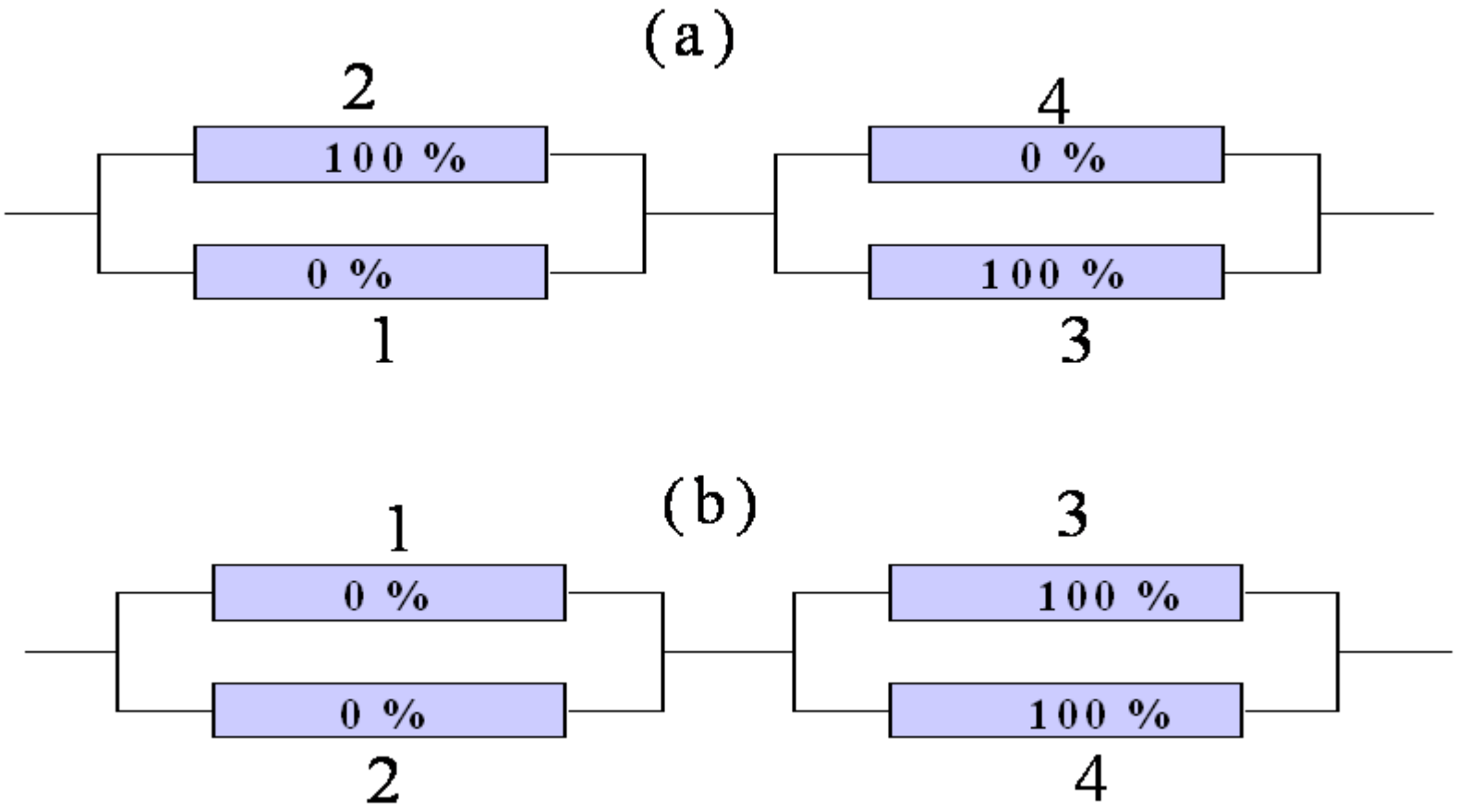
Configuration: 2S2P (4 cells)



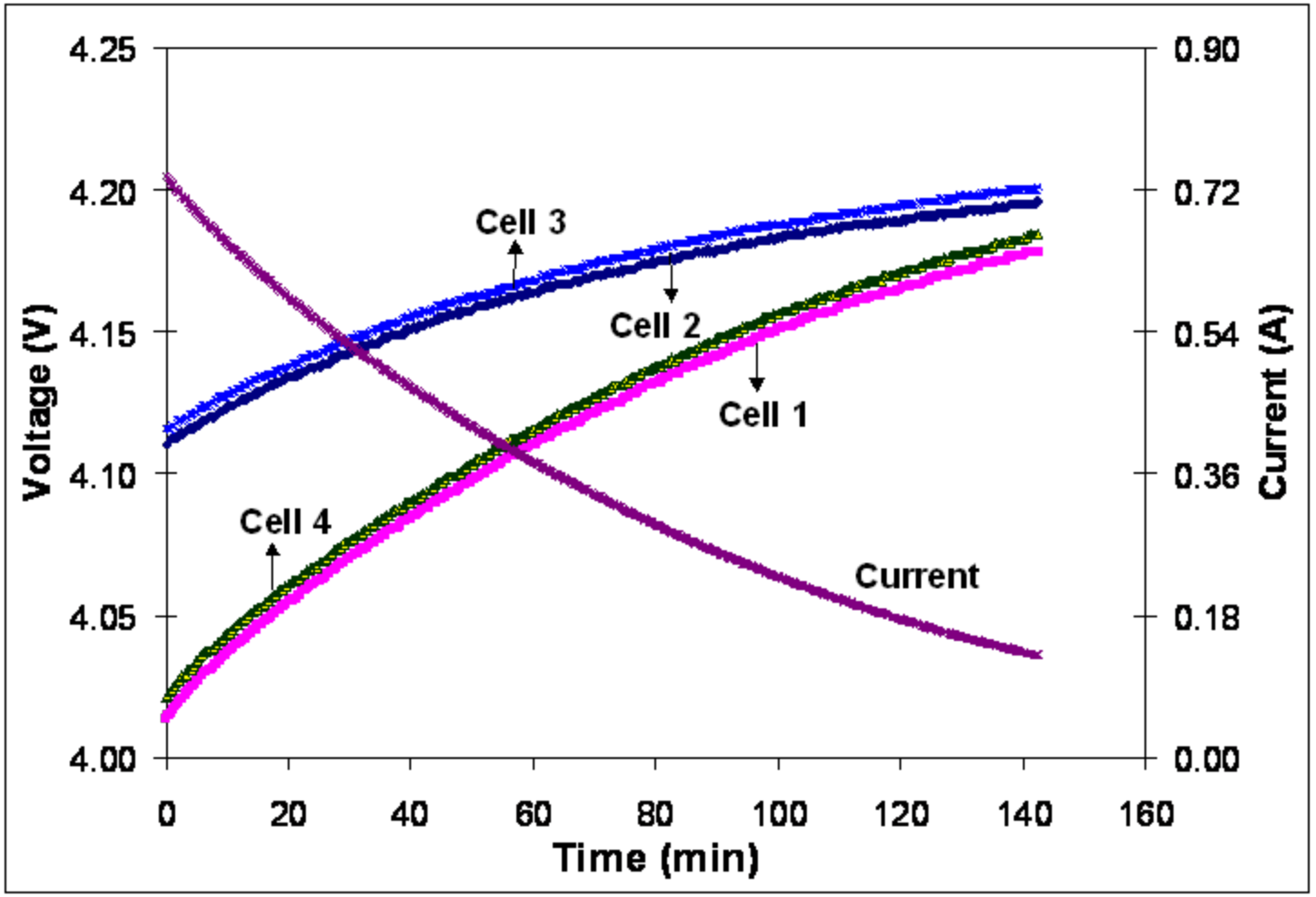
Typical Characteristics of the Canon BP 930 Battery While Being Charged on a Canon CA910 Charger



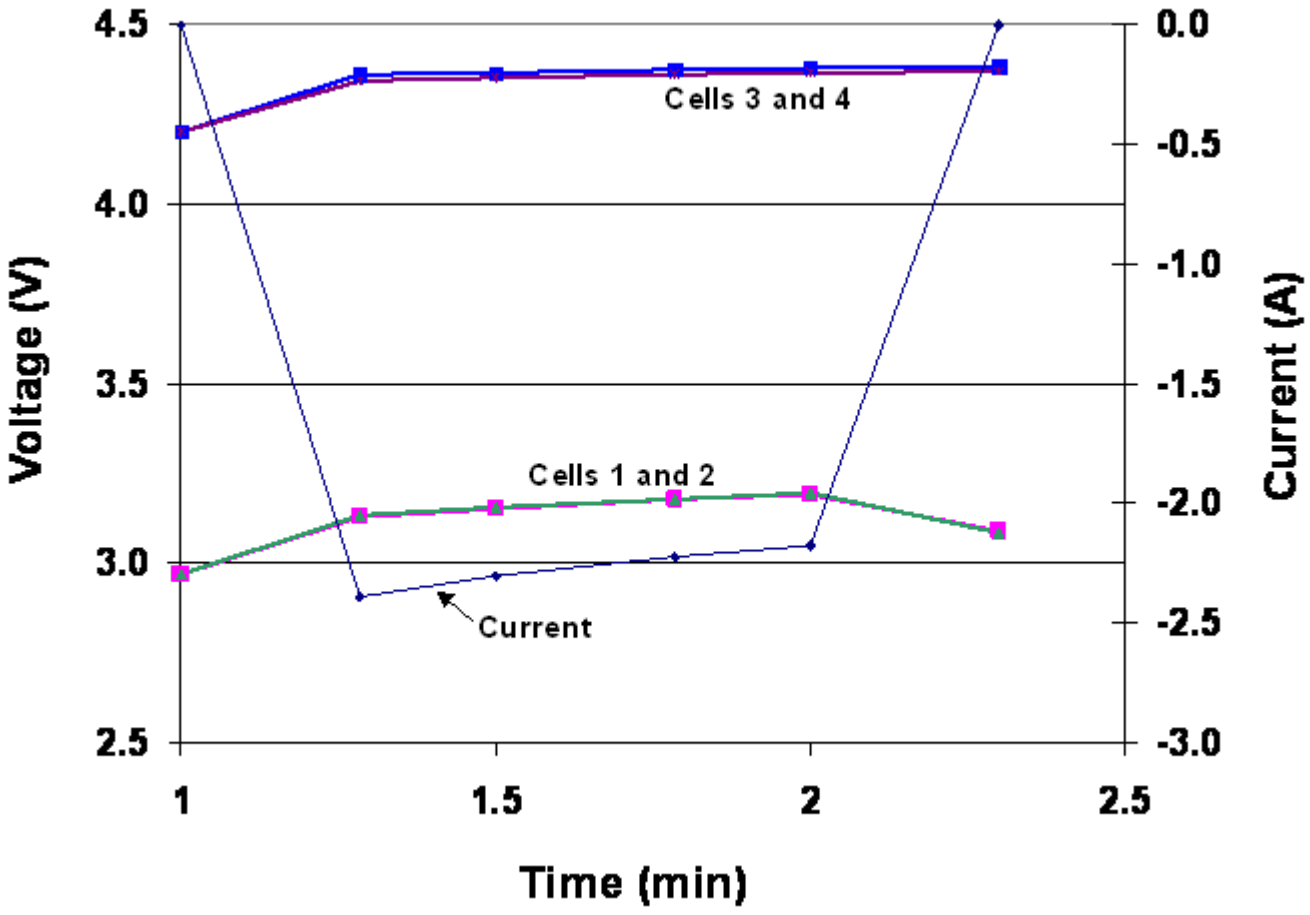
Canon BP 930 Li-ion Battery
Parallel (a) and Series (b) Imbalance Configurations



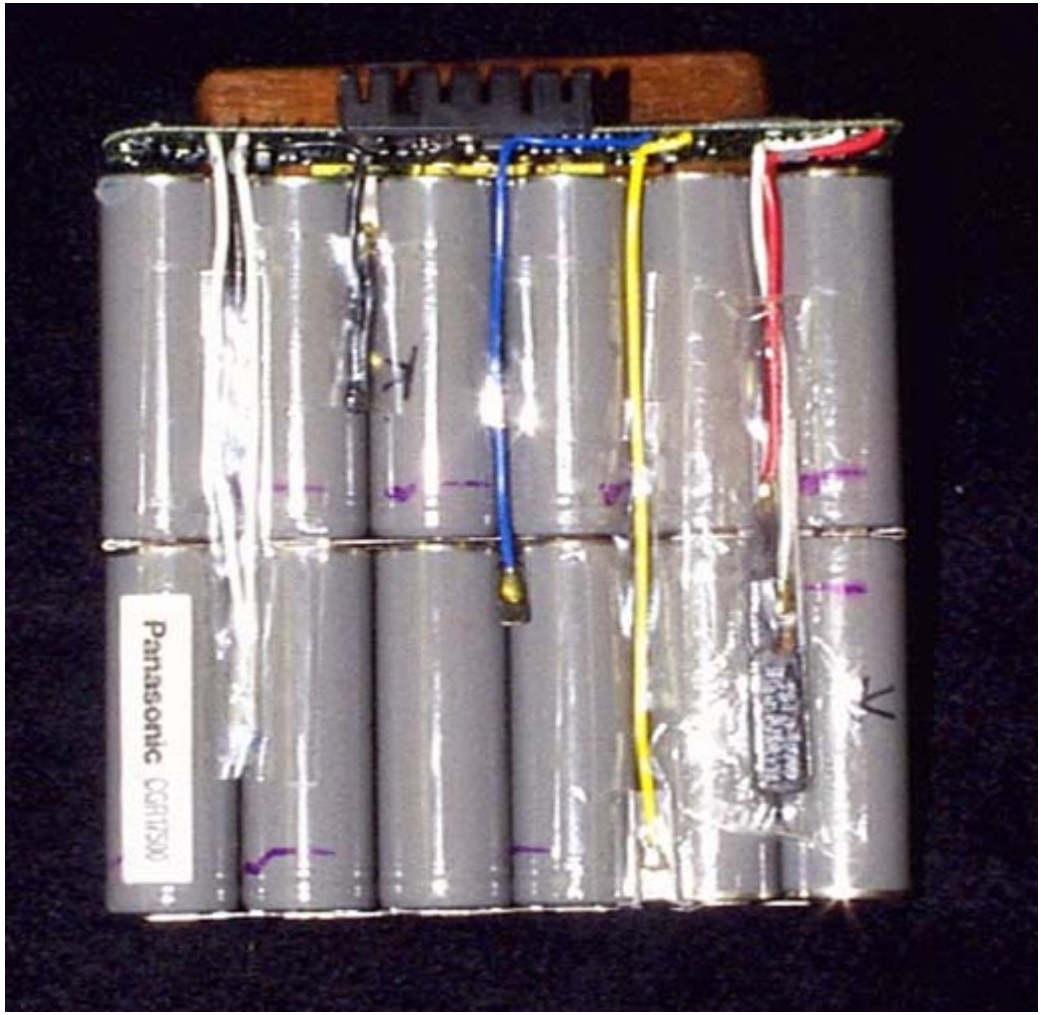
Current and Voltage Profile for the Parallel Imbalance Configuration Test



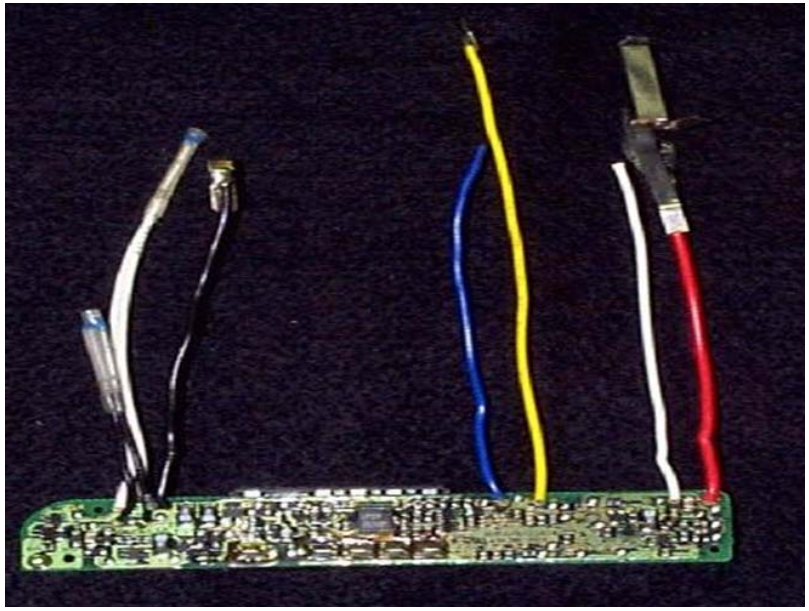
Voltage and Current Profiles for the Series Imbalance Test



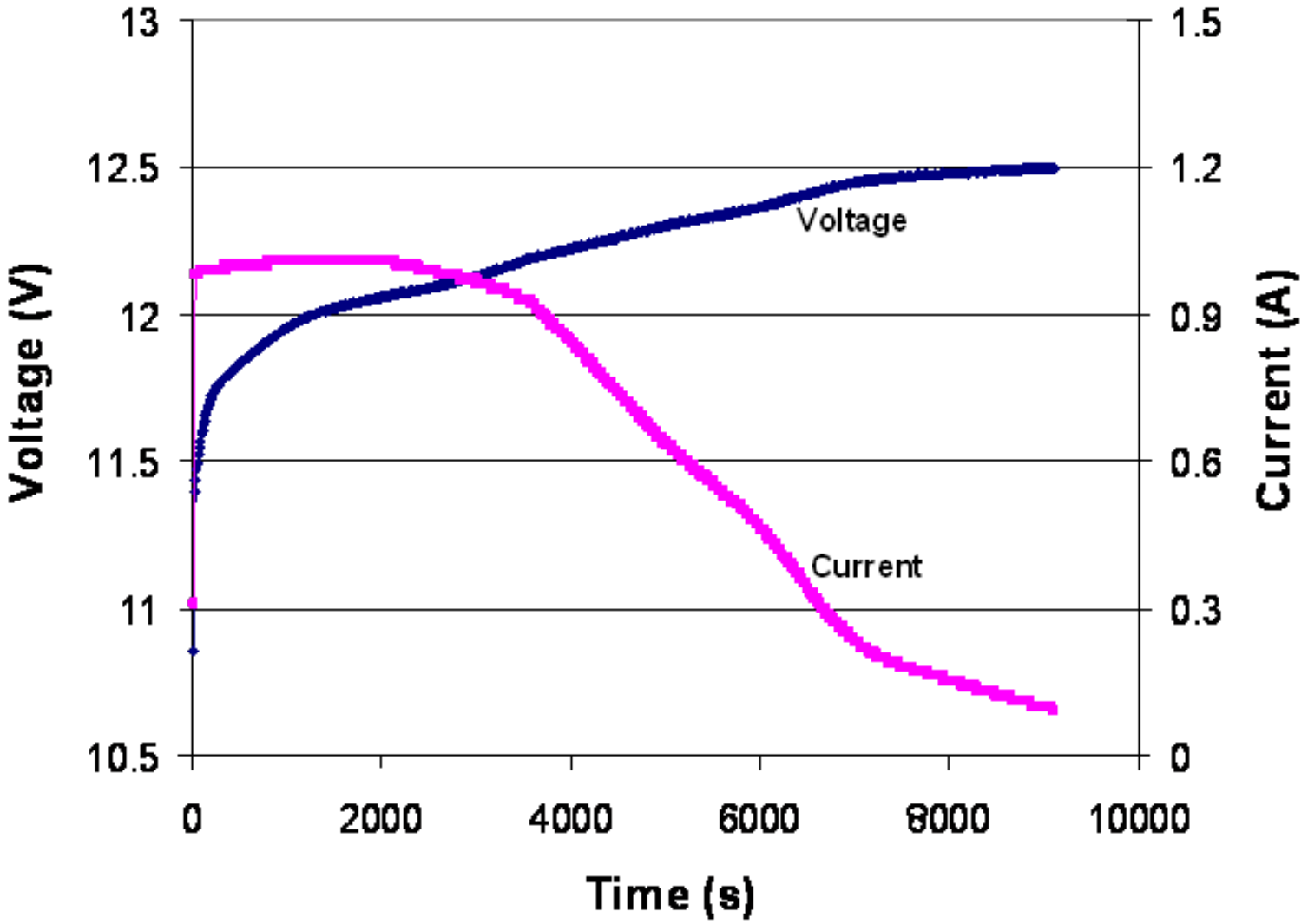
Panasonic Lithium-ion IBM Thinkpad Battery



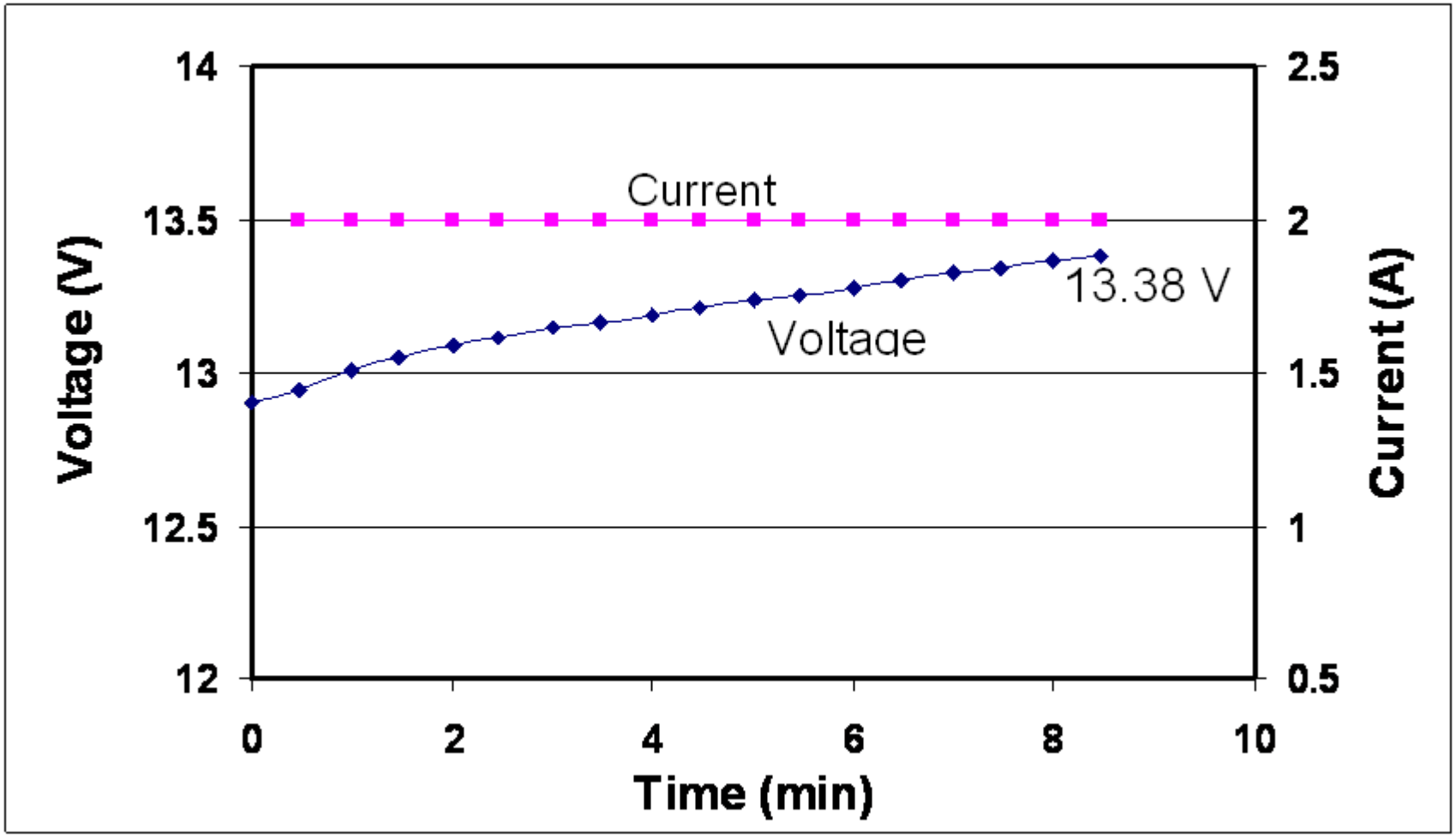
Weight: 366 g
Dimensions: 4”X 4.5”
Voltage: 10.8 V
Capacity: 3.0 Ah
Configuration: 4P3S (12 cells)



Typical Voltage and Current Profile During Charge of a Panasonic Lithium-ion Battery in the IBM Thinkpad

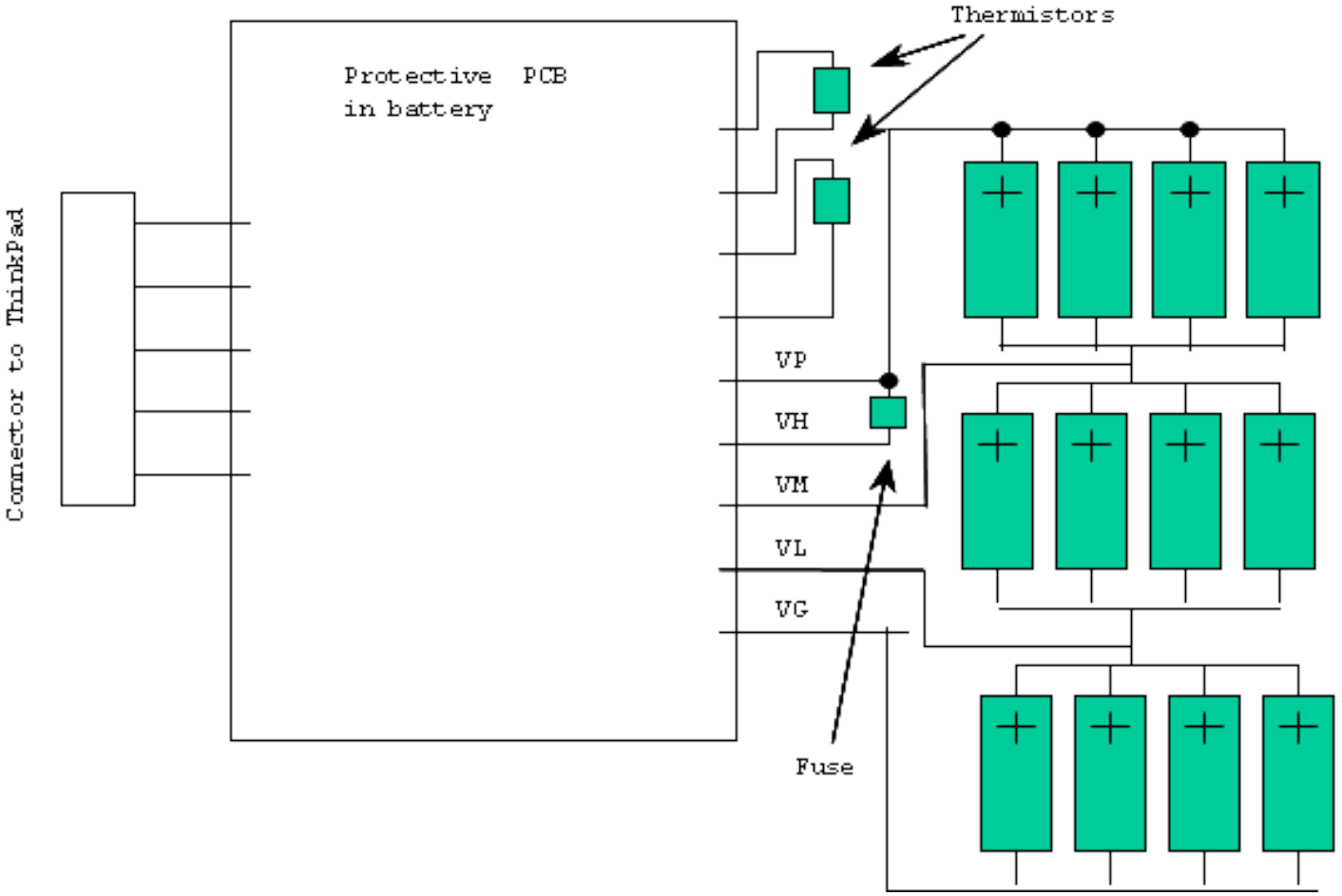


Overcharge of the Panasonic Lithium-ion Battery

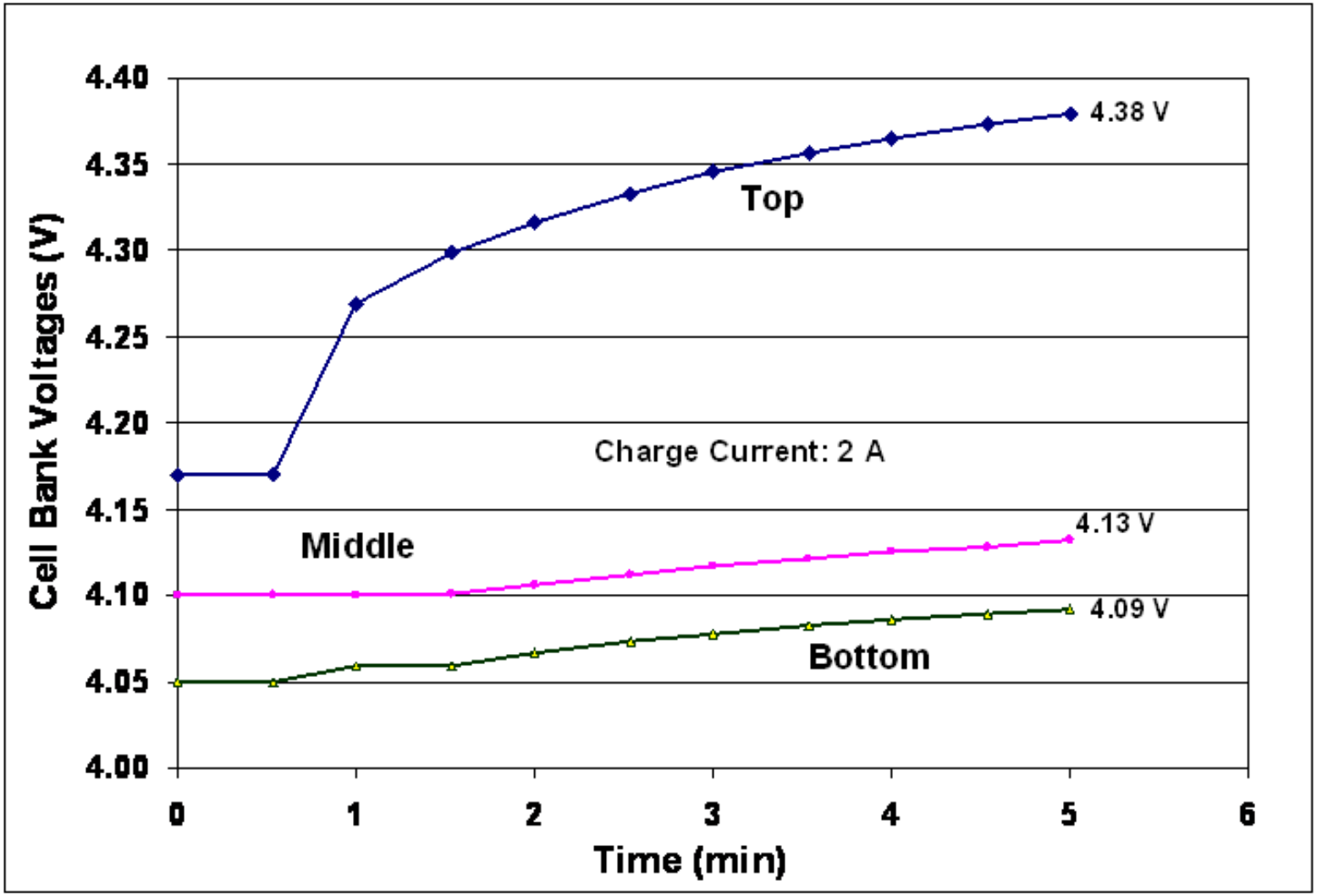


Circuit Board in the Panasonic Lithium-ion Battery

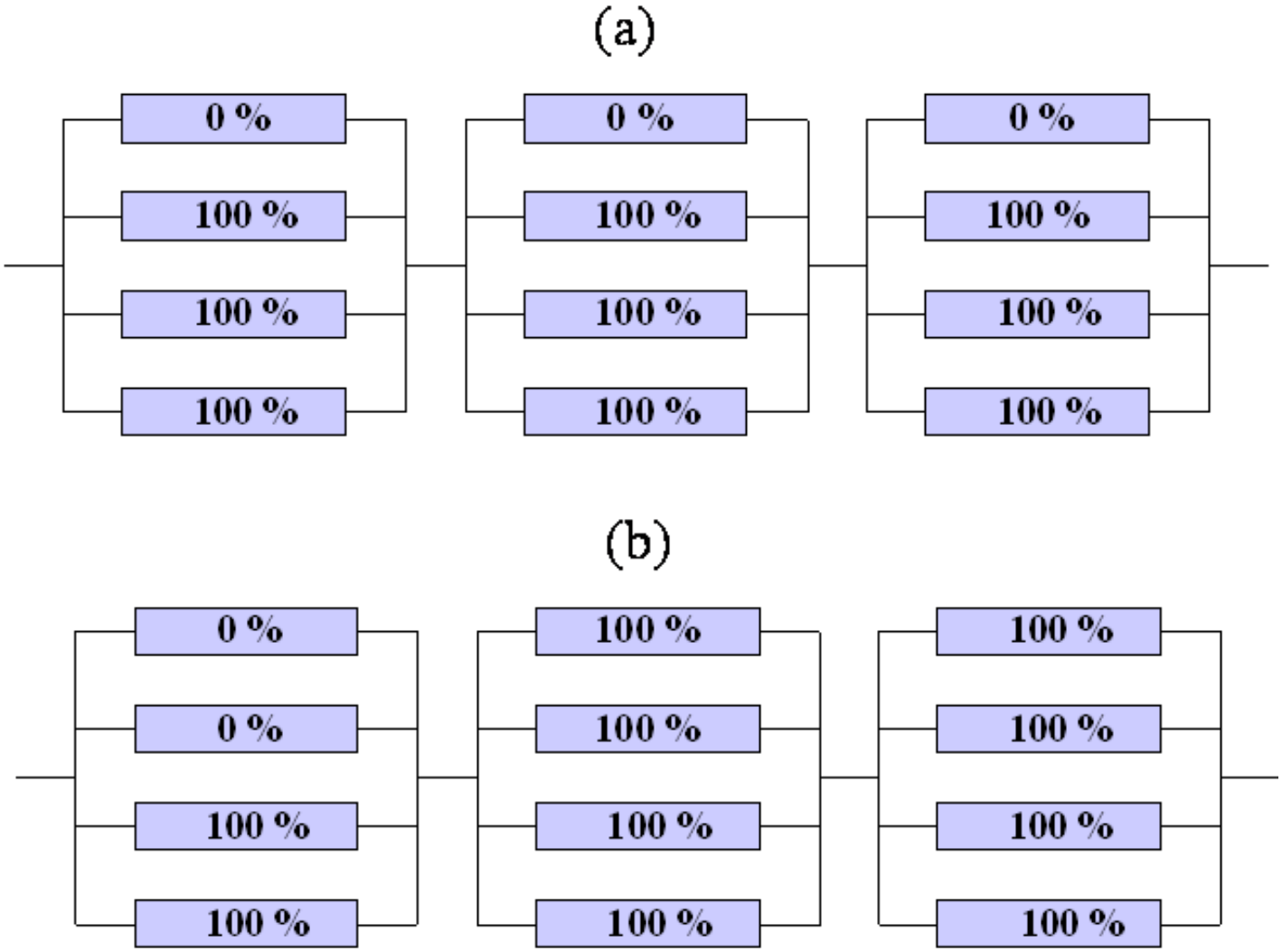
- **Firmware controls charge/discharge switches based on cell bank characteristics**
- **Capacity gauge function is performed**
- **Cell balancing carried out with small loads (15 mA) on banks**



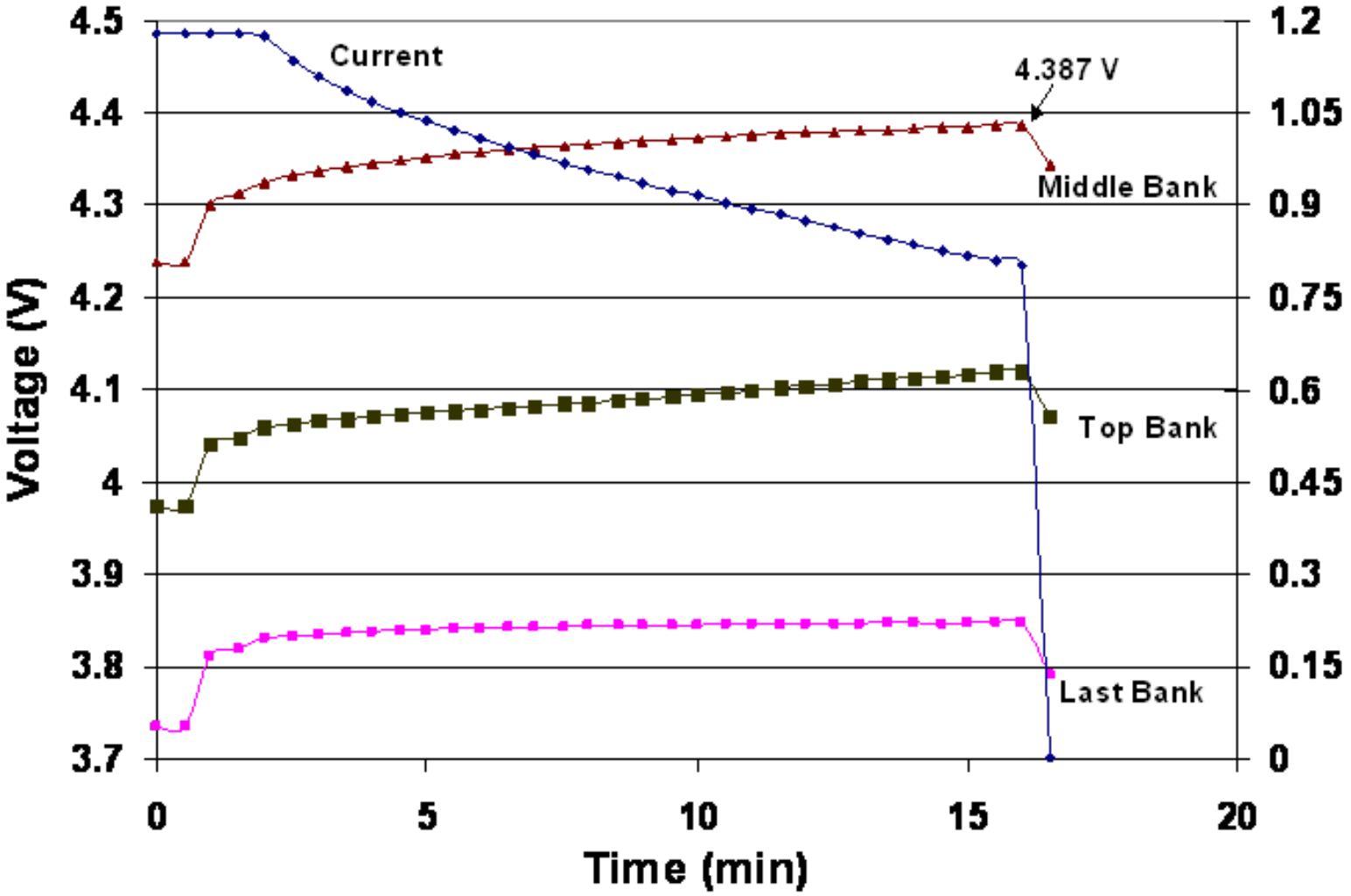
Voltage Profile for the Individual Cell Banks During Overcharge of the Top Cell Bank



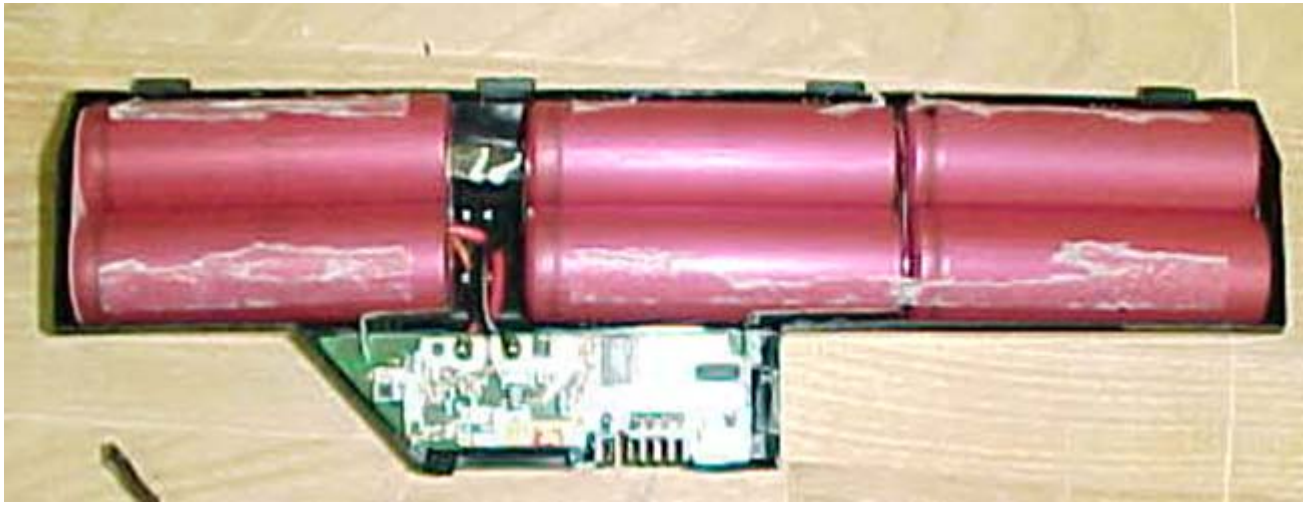
Parallel (a) and Series (b) Imbalance Configurations for the Panasonic Lithium-ion Battery



Charge Profile for the Panasonic Lithium-ion Battery During an Unbalanced Parallel Configuration of the Cell Banks



A31P IBM Thinkpad Battery



Physical Characteristics:

Weight: 318.1 ± 1.0 g

Height: 24.9 ± 0.3 mm

Length: 215.6 ± 0.6 mm

Thickness: 40.6 ± 1.2 mm

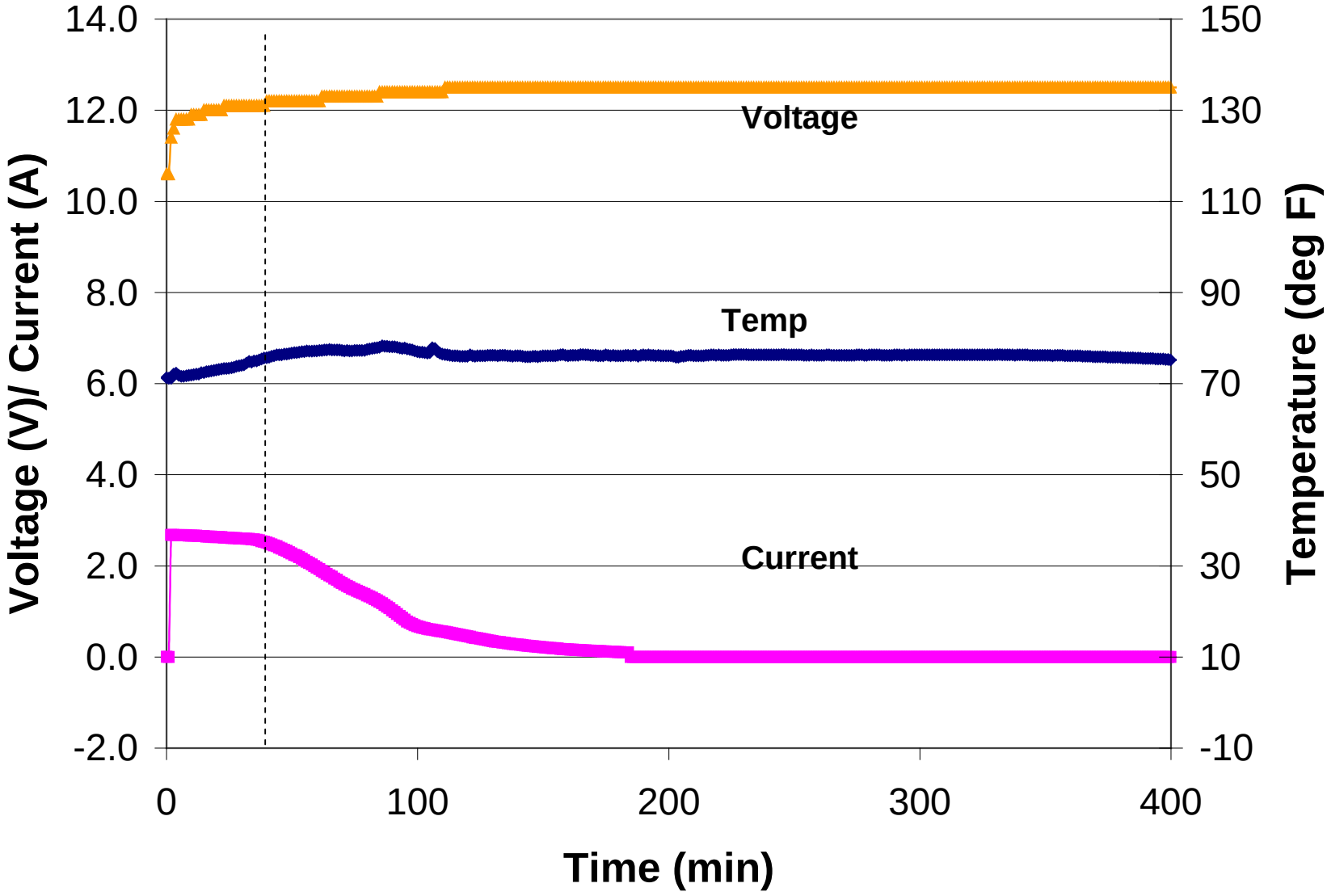
Electrochemical Characteristics:

OCV at full charge: 12.6 V

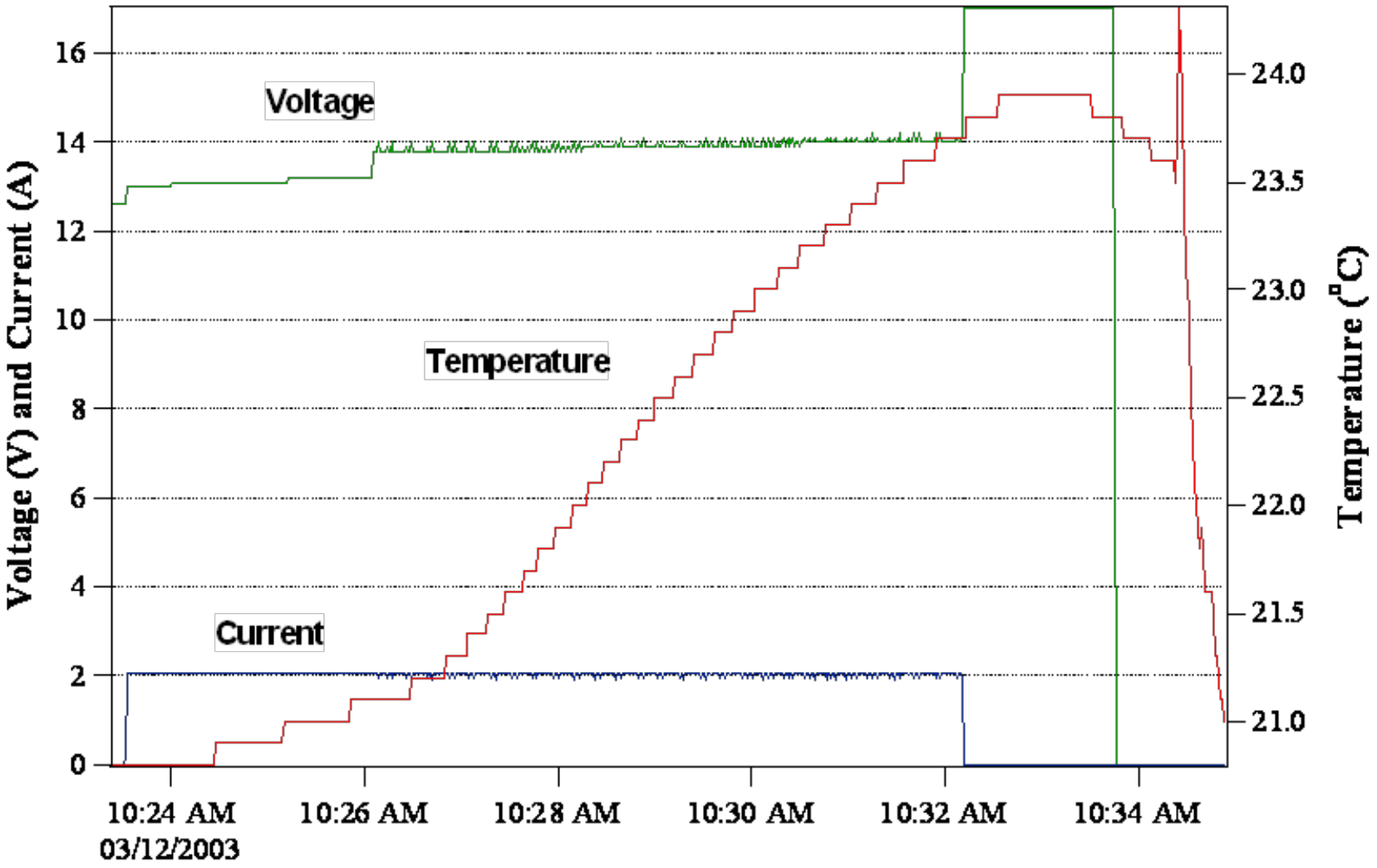
Nominal : 10.8 V

Capacity: 4.0 Ah

A31P IBM Thinkpad Sanyo Battery
Typical Charge in aThinkpad



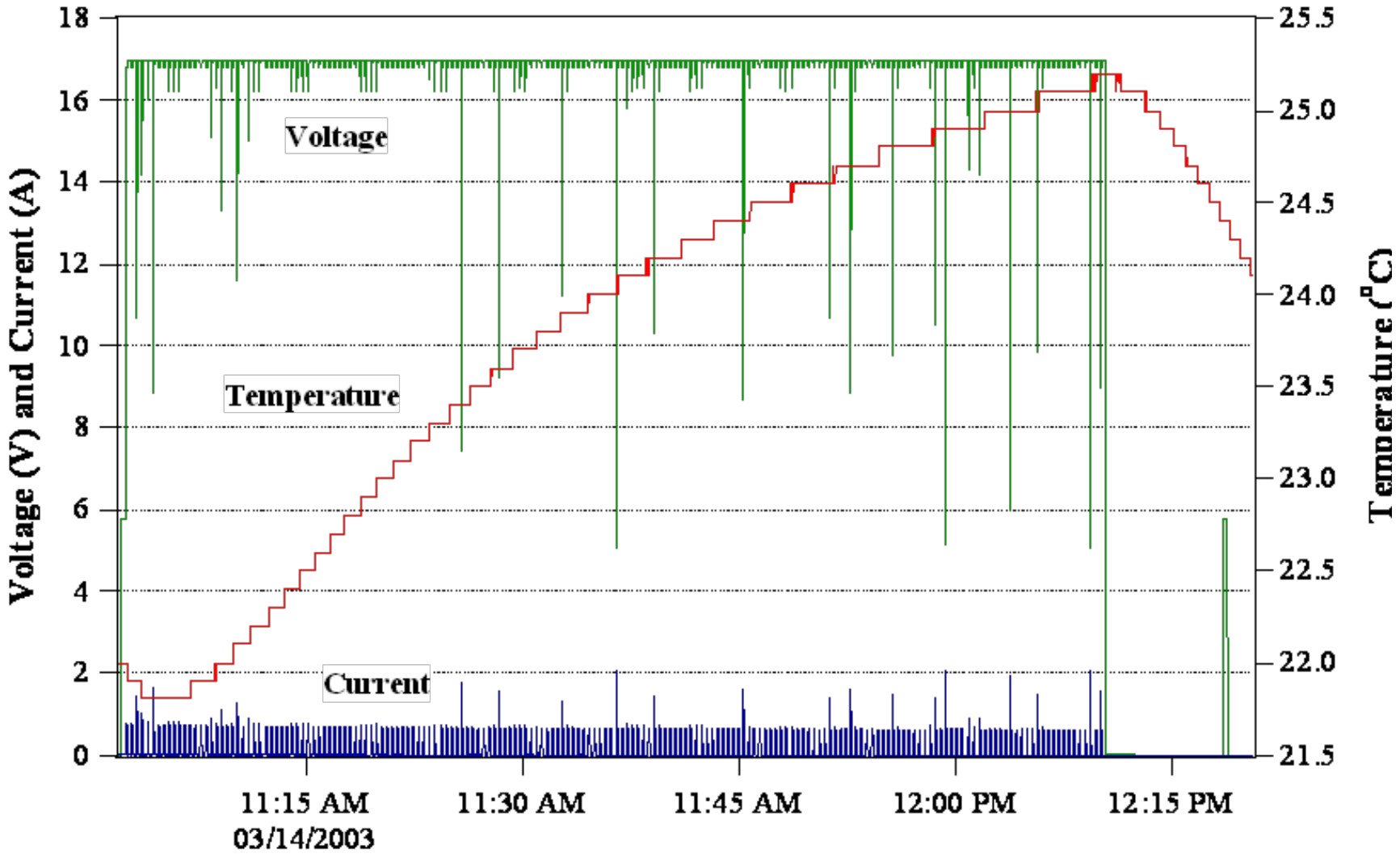
Overcharge Test of Panasonic Battery in A31P Thinkpad



Cutoff Voltage : 14.1 V; Repeated overcharge permanently shuts down the battery that can be reset only at the manufacturer's facility.

Overcharge of Individual Cell Bank in the Thinkpad A31P Panasonic Battery

Battery does not accept any charge

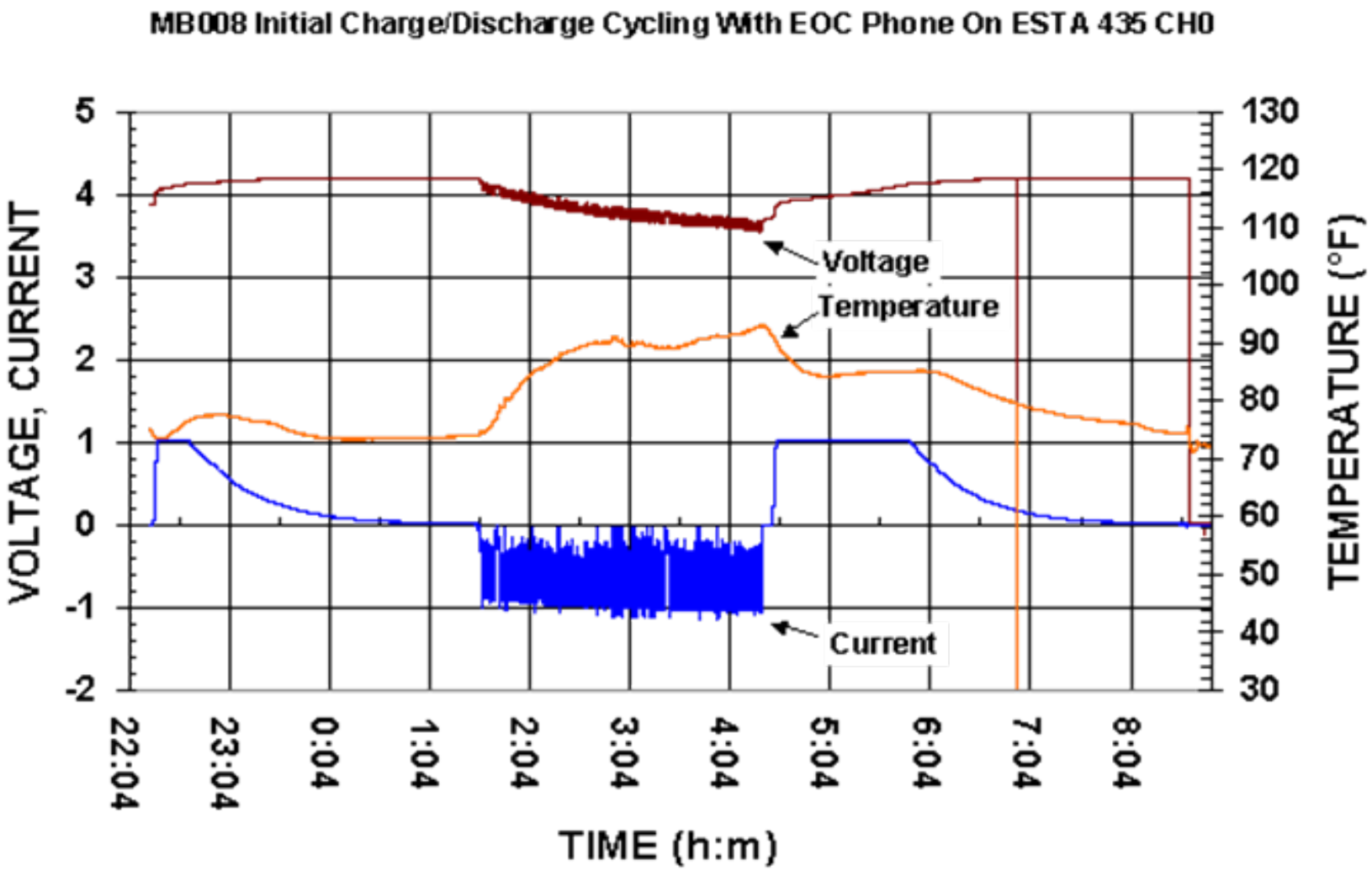


Iridium Satellite Phone Battery (ISP Battery)

Battery: 3.8 V; 1900 mAh
Mass: 92.7 g
Overvoltage (2) and Undervoltage MOSFETS

Cell: 3.8 V; 950 mAh
Mass: 39.6 g
R_e: 85 mohms

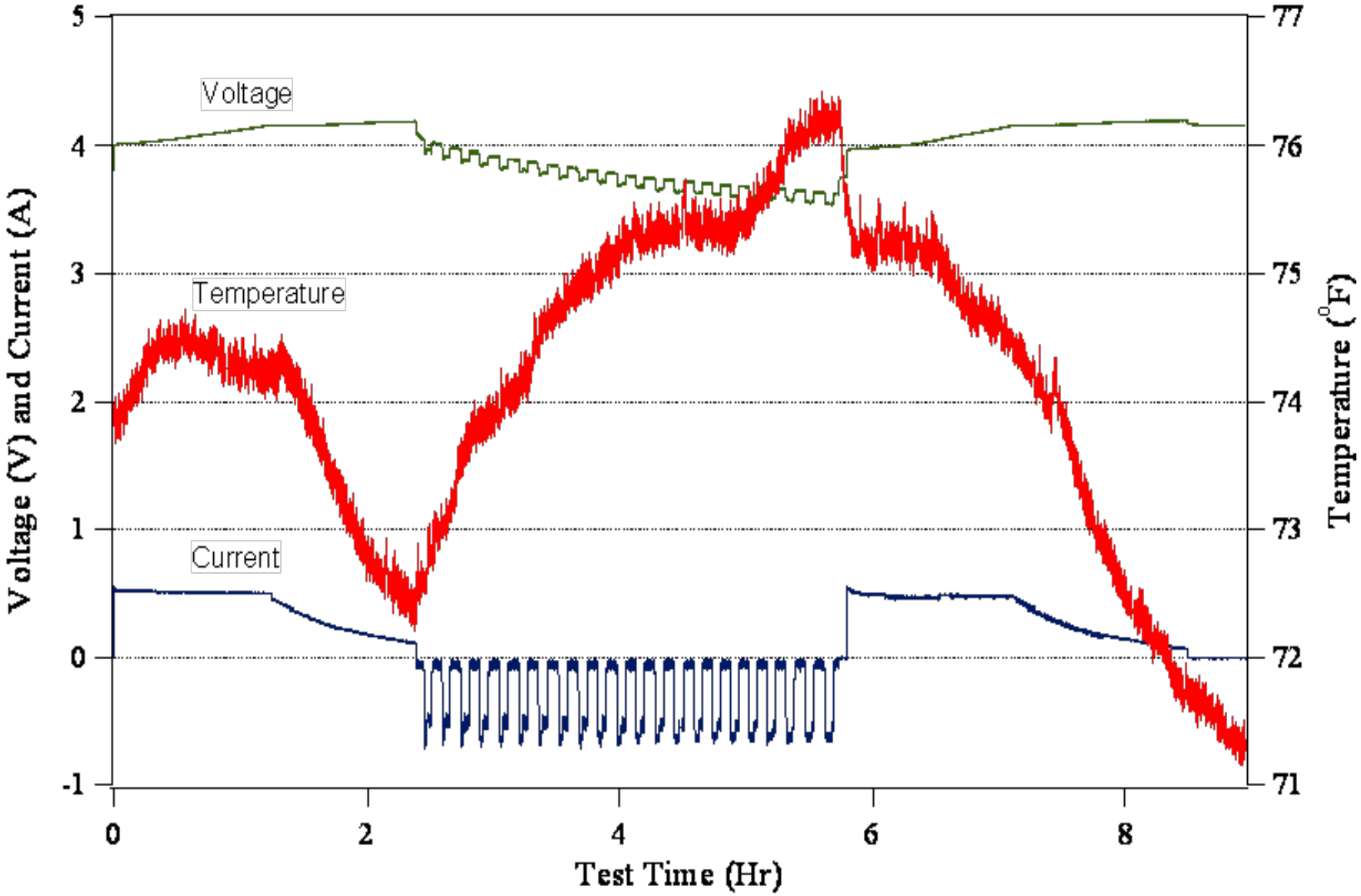
Typical Charge / Discharge Characteristics of ISP Battery in the Phone



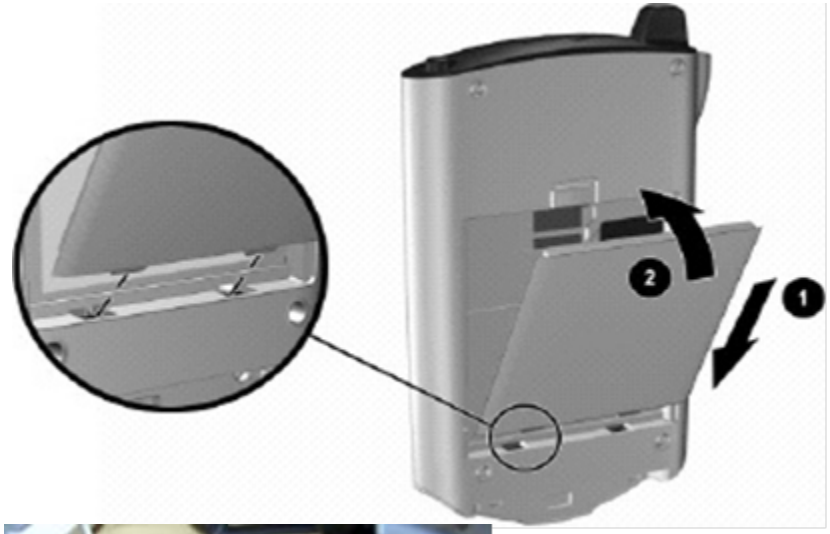
HandSpring PDA

Battery : Single Prismatic Cell
3.8 V; 1.5 Ah;
Mass: 43 g (cell only: 40.8 g,
rest is casing and circuit board)

Typical Charge/Discharge Characteristic of the HSP Battery in PDA

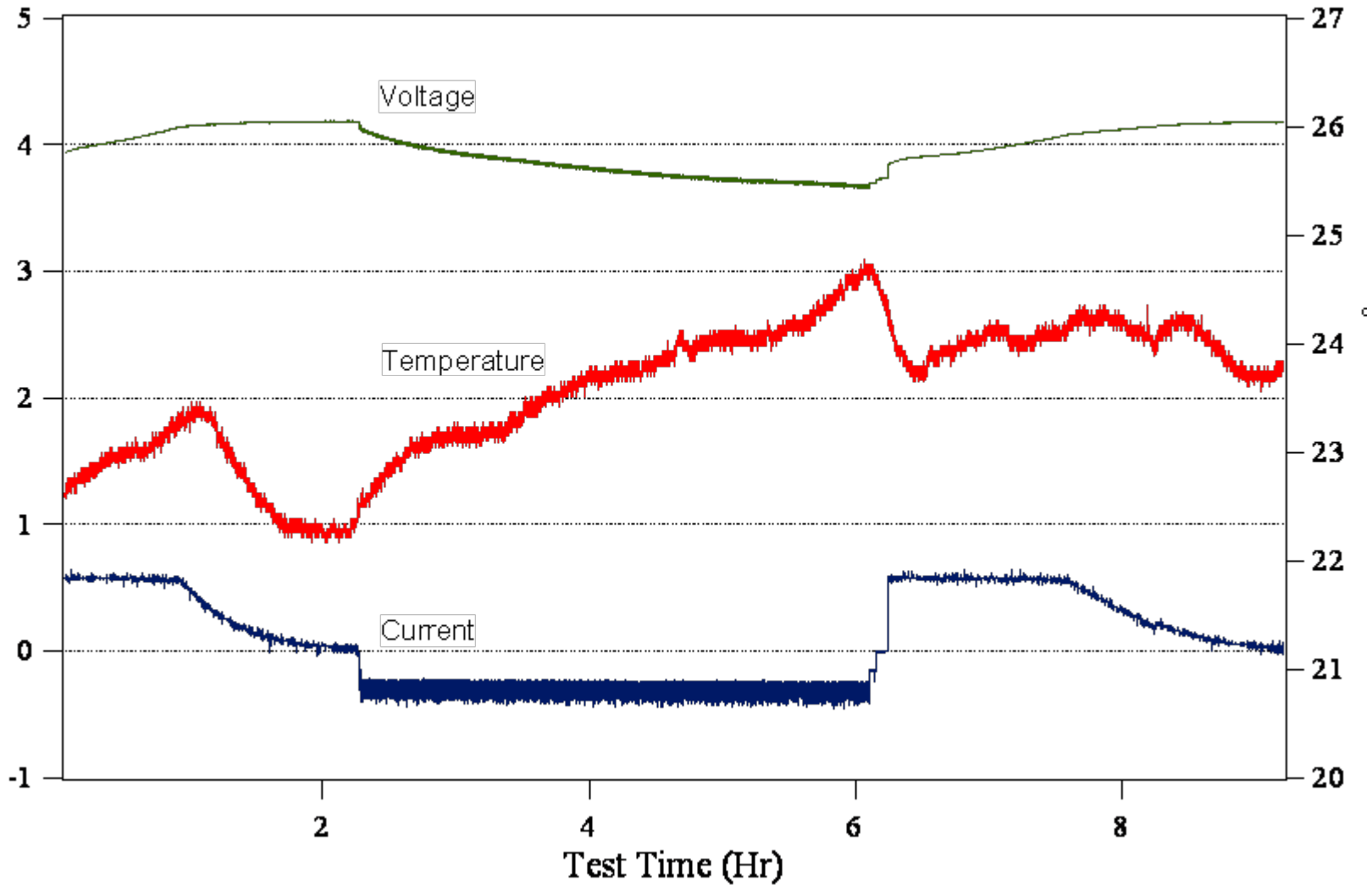


HP PDA Li-ion Battery

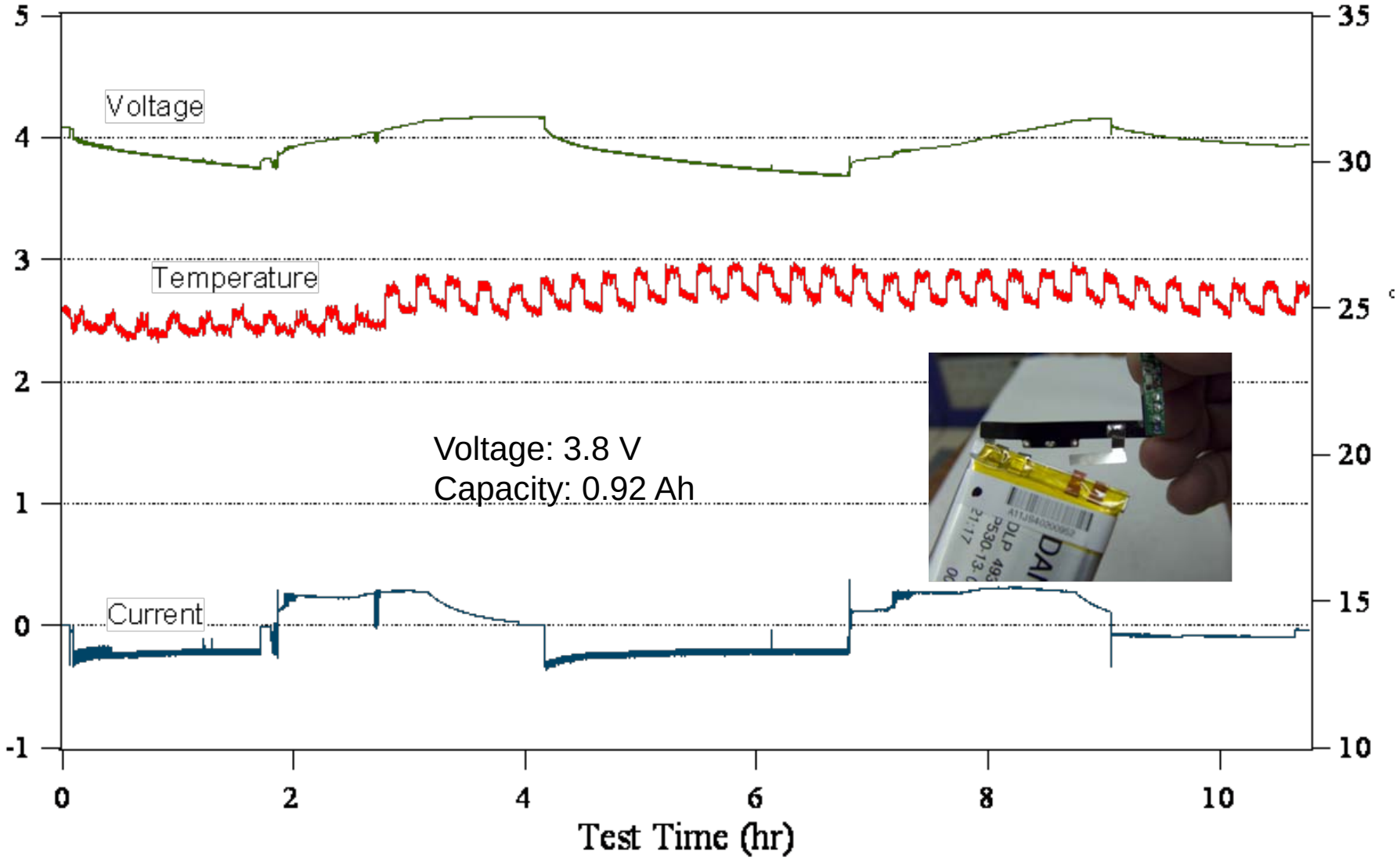


Voltage: 3.8 V
Capacity: 1.24 Ah

Typical Charge and Discharge of Li-ion Battery in HP PDA

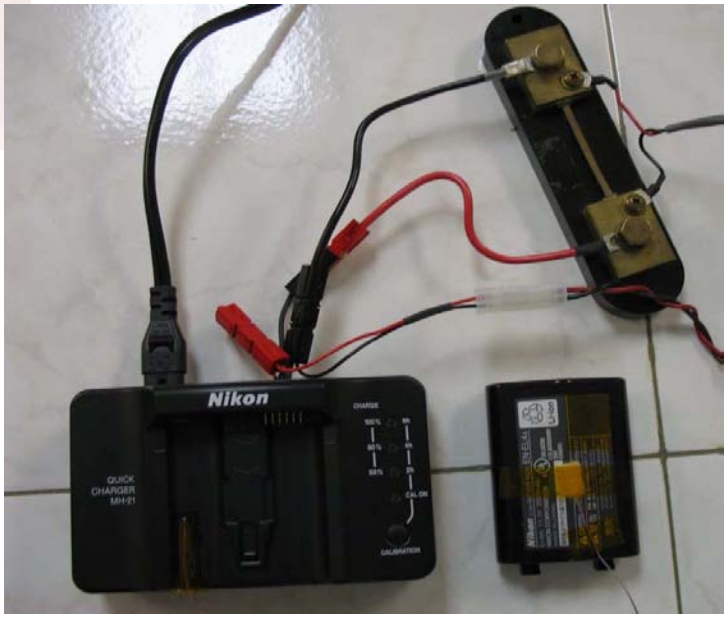


HP- PDA Li-ion Polymer Expansion Pack Battery

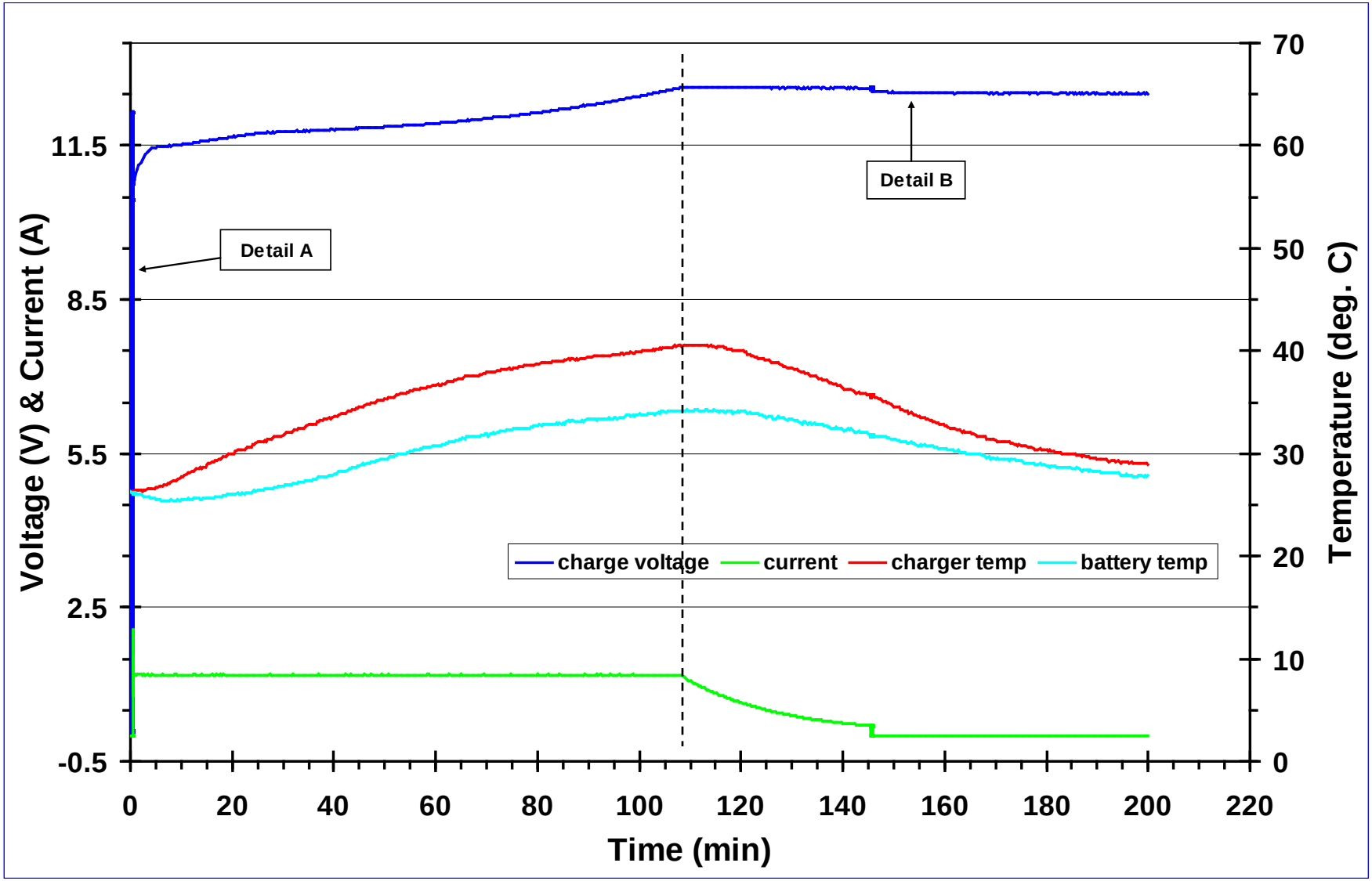


Nikon EN-EL4a Li-ion Battery

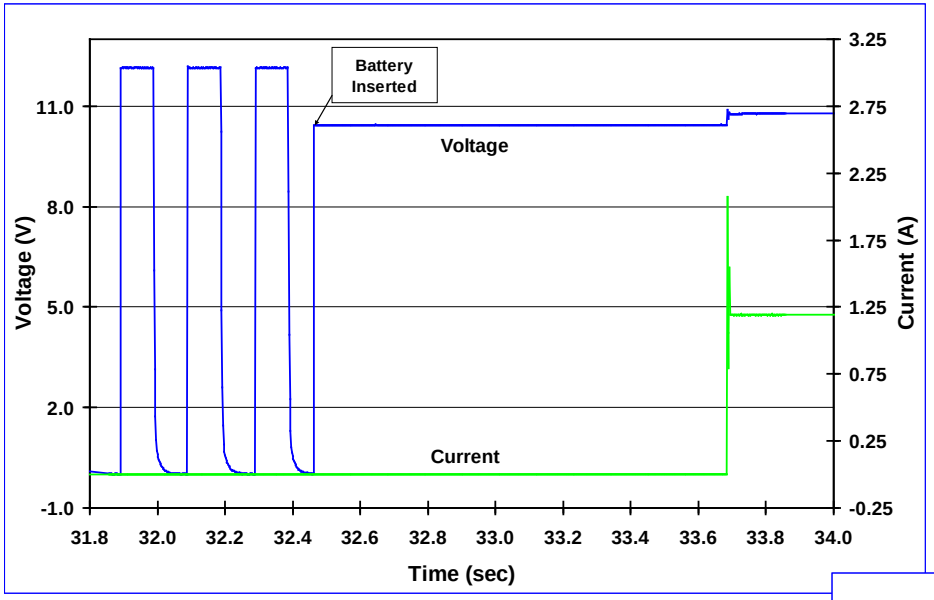
Voltage: 11.1 V
Capacity: 2.5 Ah
Sanyo Li-ion Cells in 3S



Nikon EN-EL4a Li-ion Battery Charge Characteristics in Camera

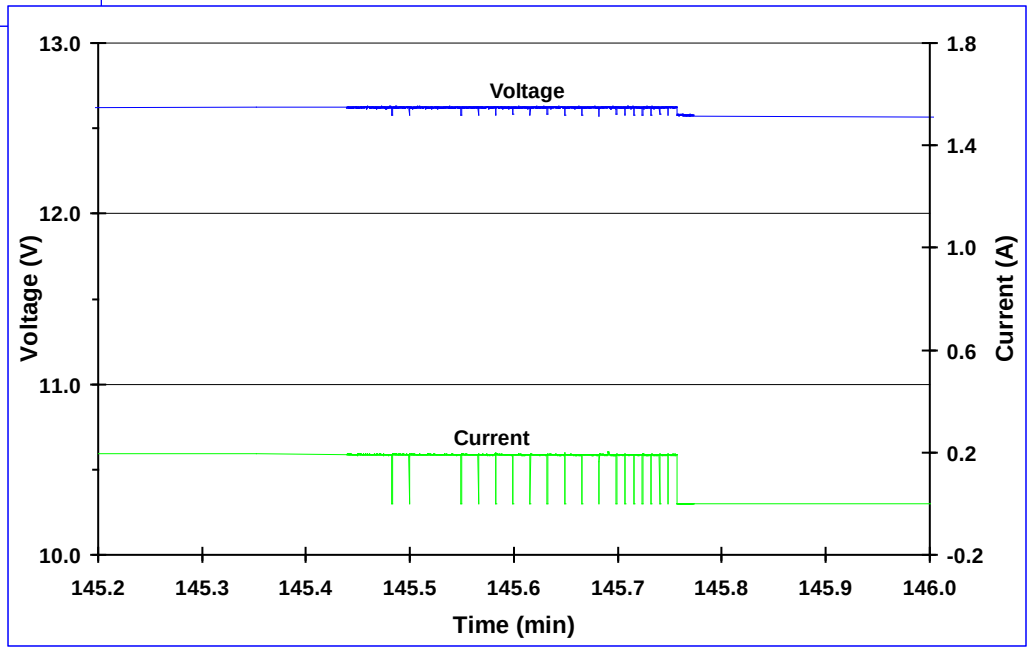


Details of Charge Profile for the Nikon Li-ion Battery



Detail A

Detail B



Summary and Conclusions

- **Charging of most Commercial-off-the-shelf batteries can be carried out with either a dedicated charger or test equipment**
  - Some require closure of the communication loop between battery and charger and hence cannot be charged using test equipment /power supplies
- The charge current seems to typically start dropping off before the voltage reaches 4.2 V/cell; but there is a steady increase in voltage until the end of charge voltage is reached.
- Due to individual cell /cell bank monitoring, unbalanced cell voltage conditions reduce the current used in the charging process.
- Unbalanced cell conditions also have a limit on charge once any one cell bank reaches the safe voltage limit (~ 4.3 V)
- COTS batteries should be charged only with their dedicated COTS chargers

Acknowledgment

Several Test Services in the Past 11 years:

SRI

API

Energy Systems Test Area- NASA- Johnson Space Center

Programs for Funding the work – Shuttle, ISS