Lithium-ion Battery Charge Methodologies Observed with Portable Electronic Equipment

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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)
  - Satellite 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.
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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

![Graph showing voltage and current over time for charging the Canon BP 930 battery.](image)
Canon BP 930 Li-ion Battery
Parallel (a) and Series (b) Imbalance Configurations

(a)

2

100 %

0 %

1

(b)

1

0 %

0 %

2

4

0 %

100 %

3

3

100 %

4
Current and Voltage Profile for the Parallel Imbalance Configuration Test
Voltage and Current Profiles for the Series Imbalance Test

![Graph showing voltage and current profiles for Cells 1 and 2, and Cells 3 and 4 over time.](image)
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

![Graph showing voltage and current over time. The voltage starts at 13 V and increases to 13.38 V at 10 minutes. The current remains constant at 1.35 A.]
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

Charge Current: 2 A

- Top: 4.38 V
- Middle: 4.13 V
- Bottom: 4.09 V
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 a Thinkpad

Time (min)
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

Voltage: 3.8 V
Capacity: 0.92 Ah

Test Time (hr)
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

![Graph of battery charge characteristics]

- **Detail A**
- **Detail B**

- Charge voltage
- Current
- Charger temp
- Battery temp
Details of Charge Profile for the Nikon Li-ion Battery

Battery Inserted

Voltage

Current

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
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