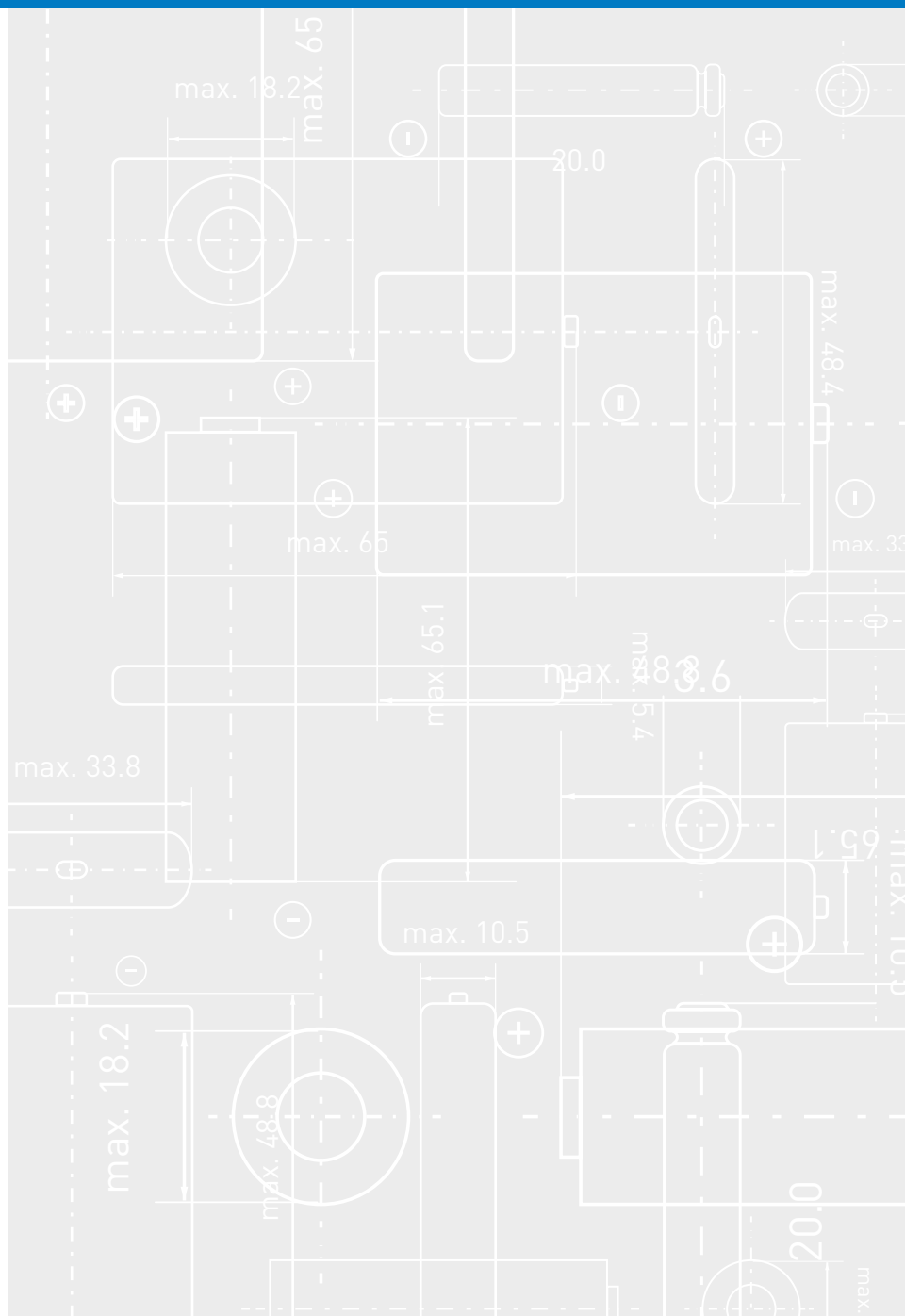


LITHIUM-ION HANDBOOK

INDUSTRIAL BATTERIES FOR PROFESSIONALS

APPLICATIONS

- ⊗ Power tool
- ⊗ Garden tool
- ⊗ Emergency lighting
- ⊗ UPS system
- ⊗ Portable POS terminal
- ⊗ GPS device
- ⊗ Shaver
- ⊗ E-bike
- ⊗ Pedelec, etc.



NOTICE TO READERS

It is the responsibility of each user to ensure that each battery application system is adequately designed safe and compatible with all conditions encountered during use, and in conformance with existing standards and requirements. Any circuits contained herein are illustrative only and each user must ensure that each circuit is safe and otherwise completely appropriate for the desired application.

This literature contains information concerning cells and batteries manufactured by Matsushita Battery Industrial Co., Ltd. This information is generally descriptive only and is not intended to make or imply any representation guarantee or warranty with respect to any cells and batteries. Cell and battery designs are subject to modification without notice. All descriptions and warranties are solely as contained in formal offers to sell or quotations made by Matsushita Battery Industrial Co., Ltd., Panasonic Sales Companies and Panasonic Agencies.

Lithium Ion Batteries

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Please see latest information at our web site

<http://industrial.panasonic.com/jp/>

※ The contents of this handbook are subject to change without notice due to improvements.

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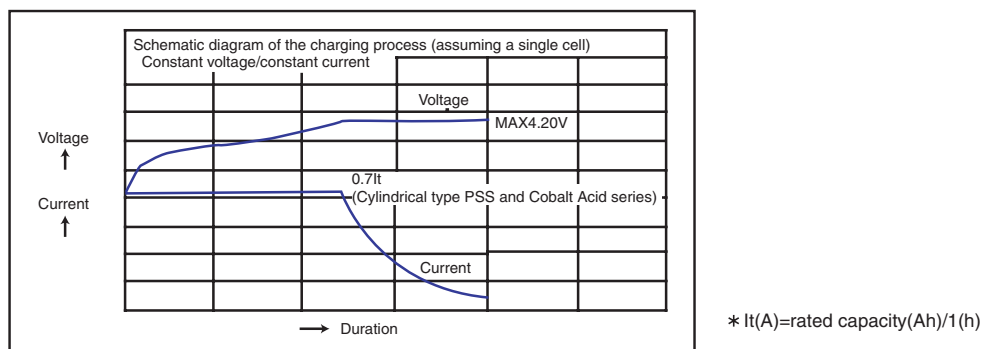
Notes and Precautions

• Safety Precautions for the Lithium Ion Batteries use and Designing Equipment.

In general, lithium ion batteries are used in battery-packs that contain both lithium ion batteries and battery safety circuits. Both items are sealed in a container made of a material such as resin so that the battery-pack cannot be easily disassembled.

1. Charging the Batteries

The “constant voltage/constant current” method is used to charge lithium ion batteries. (See Figure below)



(1) Charge Voltage

The maximum voltage is 4.2 V x the number of cells connected in series.

(2) Charge Current

We recommend the following current.

NNP series Cylindrical type : 0.3 It , Prismatic type : 0.7 It

PSS and Cobalt acid series Cylindrical type : 0.7 It , Prismatic type : 1.0 It (or 0.7 It for certain models)

When the voltage per cell is 2.9V or less, charge using a charge current of 0.1It or less.

(contact Panasonic for information regarding pulse charging.)

(3) Charge Temperature

The batteries should be charged at temperatures between 0°C and 45°C.

(4) Reverse-polarity Charging

Verify the polarity of the batteries before charging to insure that they are never charged with the polarity reversed.

2. Discharging the Batteries

(1) Discharge Current

The current should be maintained at 1.0 It or less (contact Panasonic if you plan to discharge the batteries with a current in excess of 1.0 It).

(2) Discharge Temperature

The batteries should be discharged at a temperature between -10°C and +60°C.

(contact Panasonic if you plan to discharge the batteries at temperatures less than -10°C.)

(3) Discharge Termination Voltage

NNP series 2.5V per cel

PSS and Cobalt acid series 3.0V per cel

Avoid discharging at voltages less than these.

Overdischarge can damage the performance of the battery. Equip the unit with a mechanism to prevent overdischarge, especially in situations where the user may forget to turn the equipment off.

3. Equipment Design

(1) Installing Battery-Packs in the Equipment

To avoid damage to the battery-pack, make sure that the battery-pack is positioned away from heat sources in the equipment or in the battery charger.

(2) Mechanisms to Prevent Dropping

Be sure to use a battery-pack lock mechanism to prevent the battery-pack from being ejected when the equipment is dropped or receives a sudden impact.

(3) Preventing Short Circuits and Reversed Connections

Use a terminal structure that makes it unlikely that the terminals will be shorted by metallic necklaces, clips, hairpins, etc. Structure the battery and the terminals to the battery in such a way that the battery-pack cannot be put in backwards when installed in the charger or the equipment.

(4) Inclusion in Other Equipment

If the battery is built into other equipment, use caution to strictly avoid designing airtight battery compartments.

(5) Terminal Materials in the External Equipment

Use materials that are highly resistant to corrosion (such as nickel or nickel-coated copper). If contact resistance is an issue, we recommend that you use contact plating (such as gold plating) on the terminals.

4. Storing the Batteries

The batteries should be stored at room temperature, charged to about 30 to 50% of capacity. We recommend that batteries be charged about once per year to prevent overdischarge.

5. Use of the Batteries

See the section on "Safety Precautions"

6. Other

(1) The Chemical Reaction

Because batteries utilize a chemical reaction they are actually considered a chemical product. As such, battery performance will deteriorate over time even if stored for a long period of time without being used. In addition, if the various usage conditions such as charge, discharge, ambient temperature, etc. are not maintained within the specified ranges the life expectancy of the battery may be shortened or the device in which the battery is used may be damaged by electrolyte leakage. If the batteries cannot maintain a charge for long periods of time, even when they are charged correctly, this may indicate it is time to change the battery.

(2) When exporting the batteries, they are likely to undergo the judgment on classification of strategic products according to the Export Trade Control Ordinance Please contact Panasonic.

7. Please Note

The performance and life expectancy of batteries depends heavily on how the batteries are used. In order to insure safety, be sure to consult with Panasonic in advance regarding battery charging and discharging specifications and equipment structures when designing equipment that includes these batteries.

Panasonic assumes no liability for problems that occur when the Notes and Precautions for use listed above are not followed.

Safety Precautions

1. When Using the Battery

DANGER

- (1) Misusing the battery may cause the battery to get hot, explode, or ignite and cause serious injury. Be sure to follow the safety rules listed below:
 - Do not place the battery in fire or heat the battery.
 - Do not install the battery backwards so that the polarity is reversed.
 - Do not connect the positive terminal and the negative terminal of the battery to each other with any metal object (such as wire).
 - Do not carry or store the batteries together with necklaces, hairpins, or other metal objects.
 - Do not penetrate the battery with nails, strike the battery with a hammer, step on the battery, or otherwise subject it to strong impacts or shocks.
 - Do not solder directly onto the battery.
 - Do not expose the battery to water or salt water, or allow the battery to get wet.
- (2) Do not disassemble or modify the battery. The battery contains safety and protection devices which, if damaged, may cause the battery to generate heat, explode or ignite.
- (3) Do not place the battery on or near fires, stoves, or other high-temperature locations. Do not place the battery in direct sunshine, or use or store the battery inside cars in hot weather. Doing so may cause the battery to generate heat, explode, or ignite. Using the battery in this manner may also result in a loss of performance and a shortened life expectancy.
- (4) Do not insert the battery into equipment designed to be hermetically sealed. In some cases hydrogen or oxygen may be discharged from the cell which may result in rupture, fire or explosion.

WARNING

- (1) Immediately discontinue use of the battery if, while using, charging, or storing the battery, the battery emits an unusual smell, feels hot, changes color, changes shape, or appears abnormal in any other way. Contact your sales location or Panasonic if any of these problems are observed.
- (2) Do not place the batteries in microwave ovens, high-pressure containers, or on induction cookware.
- (3) In the event that the battery leaks and the fluid gets into one's eye, do not rub the eye. Rinse well with water and immediately seek medical care. If left untreated the battery fluid could cause damage to the eye.

CAUTION

- (1) If the device is to be used by small children, the caregiver should explain the contents of the user's manual to the children. The caregiver should provide adequate supervision to insure that the device is being used as explained in the user's manual.
- (2) When the battery is worn out, insulate the terminals with adhesive tape or similar materials before disposal.

 **DANGER**

Be sure to follow the rules listed below while charging the battery. Failure to do so may cause the battery to become hot, explode, or ignite and cause serious injury.

- When charging the battery, either use a specified battery charger or otherwise insure that the battery charging conditions specified by Panasonic are met.
- Do not attach the batteries to a power supply plug or directly to a car's cigarette lighter.
- Do not place the batteries in or near fire, or into direct sunlight. When the battery becomes hot, the built-in safety equipment is activated, preventing the battery from charging further, and heating the battery can destroy the safety equipment and can cause additional heating, breaking, or ignition of the battery.

 **WARNING**

Do not continue charging the battery if it does not recharge within the specified charging time. Doing so may cause the battery to become hot, explode, or ignite.

2. While Charging

 **CAUTION**

The temperature range over which the battery can be charged is 0°C to 45°C. Charging the battery at temperatures outside of this range may cause the battery to become hot or to break. Charging the battery outside of this temperature range may also harm the performance of the battery or reduce the battery's life expectancy.

3. When Discharging the Battery

 **DANGER**

Do not discharge the battery using any device except for the specified device. When the battery is used in devices aside from the specified device it may damage the performance of the battery or reduce its life expectancy, and if the device causes an abnormal current to flow, it may cause the battery to become hot, explode, or ignite and cause serious injury.

 **CAUTION**

The temperature range over which the battery can be discharged is -10°C to 60°C. Use of the battery outside of this temperature range may damage the performance of the battery or may reduce its life expectancy.

To insure the safe use of this battery, contact Panasonic when designing a device that uses this battery.

Overview

*A Lithium ion battery must include a safety unit(SU). Also for safety reasons cells are not sold individually.

Dedicated to support various types of mobile equipment with its high-energy density

Lithium Ion Batteries



■ Overview

The battery is a rechargeable battery best suited to mobile devices that require small-size, light weight and high performance. Its characteristics of high energy and high voltage (3.6V) powerfully fulfill these three key requirements. Its standard battery-pack, coupled with a charger, facilitates simple equipment design.

■ Characteristics

1. Less self-discharge (approx. 1/10) compared with a Ni-MH or Ni-Cd batteries as well as no memory effect.
2. A newly developed NNP* series is achieving both high capacity & safety by the use of new positive electrode & high reliable technology by the present charging system (4.2V)
 - * NNP = Nickel oxide based New Platform
3. The PSS* series adopts nickel and the manganese in new positive electrode.
 - The safety of a battery to heat improved further.
 - * PSS = Panasonic Solid Solution

■ Structure

A lithium-ion rechargeable battery consists of a spiral structure with 4 layers. A positive electrode activated by cobalt acid lithium, a negative electrode activated by special carbon, and separator are put together in a whirl pattern and stored in the case. It also incorporates a variety of safety protection systems such as a gas discharge valve which helps prevent the battery from exploding by releasing internal gas pressure if it exceeds the design limit.

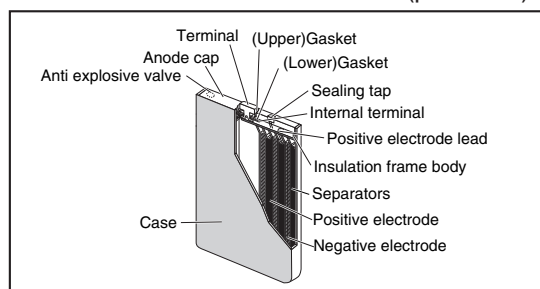
■ Safety

Our lithium ion batteries have acquired UL1642. Contact us for further details.

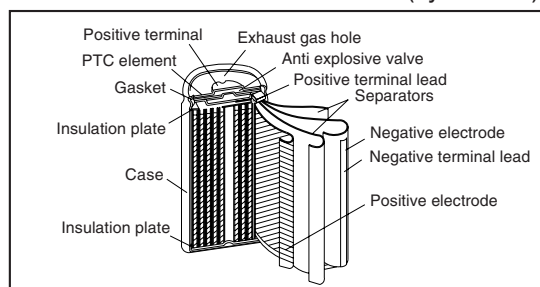
■ Applications

- Cellular phone, Note PC etc.
- DVC/DSC/DVD/Portable LCD TV etc.
- Portable CD player, MD player, Semiconductor-driven audio etc.

Structure of Lithium Ion Batteries (prismatic)



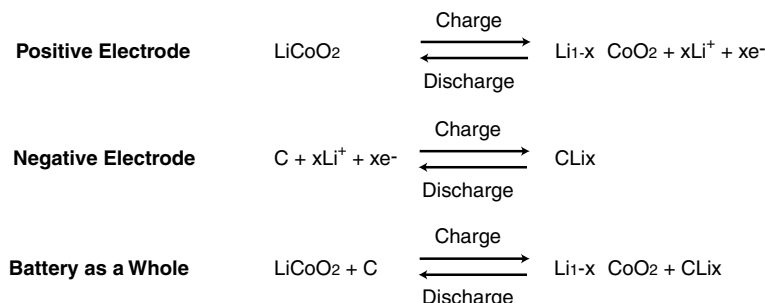
Structure of Lithium Ion Batteries (cylindrical)



● **Battery Reaction**

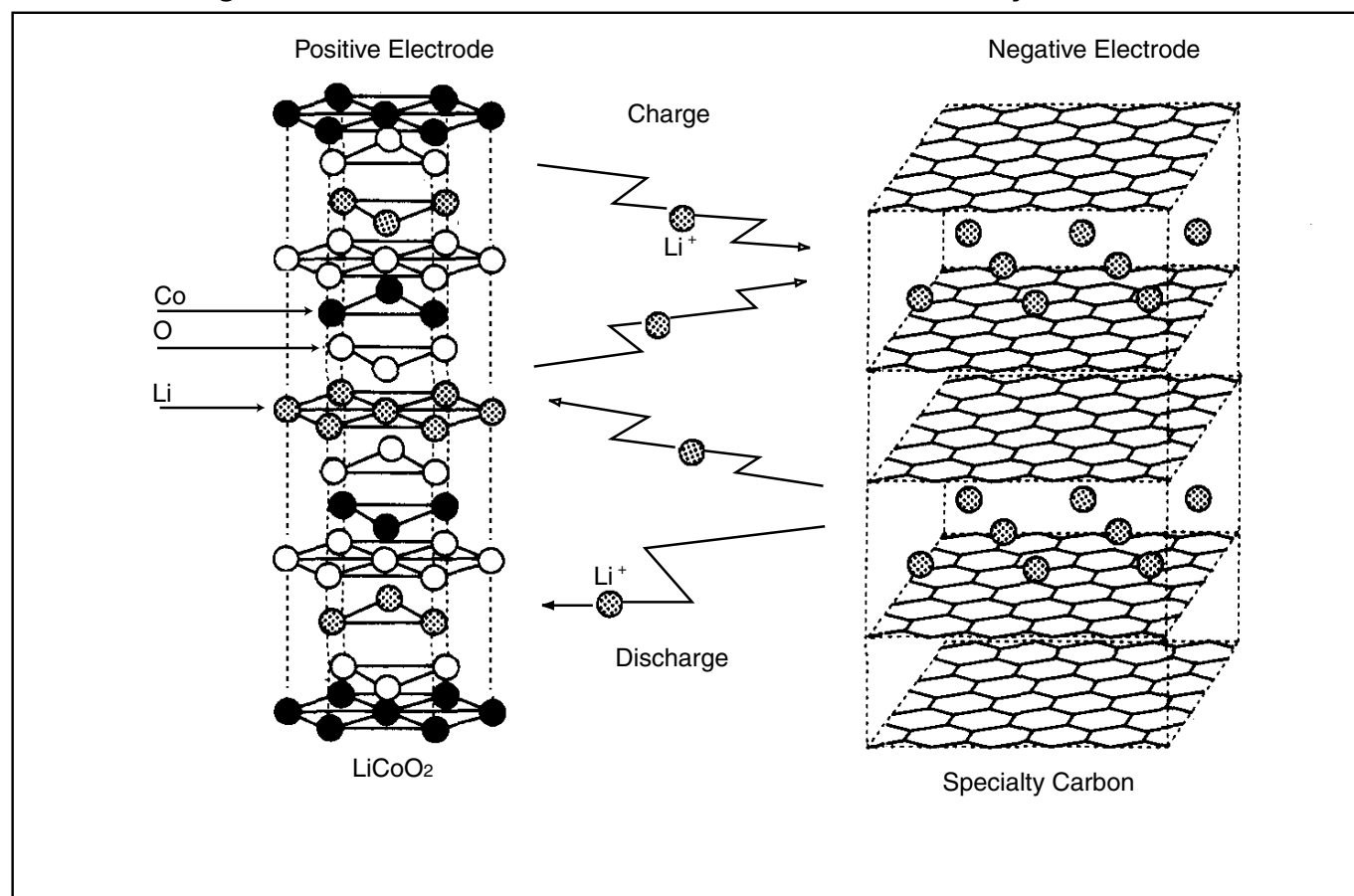
The lithium ion battery makes use of lithium cobalt oxide (which has superior cycling properties at high voltages) as the positive electrode and a highly-crystallized specialty carbon as the negative electrode. It uses an organic solvent, optimized for the specialty carbon, as the electrolytic fluid.

The chemical reactions for charge and discharge are as shown below:



The principle behind the chemical reaction in the lithium ion battery is one where the lithium in the positive electrode lithium cobalt oxide material is ionized during charge, and moves from layer to layer in the negative electrode. During discharge, the ions move to the positive electrode and return to the original compound.

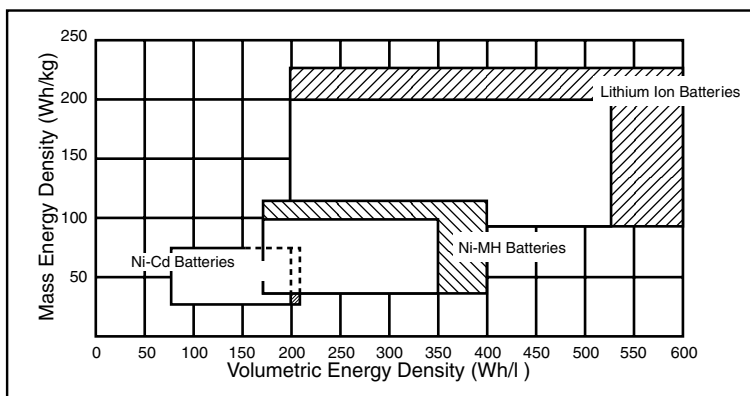
Schematic Diagram of the Chemical Reaction of the Lithium Ion Battery



Features

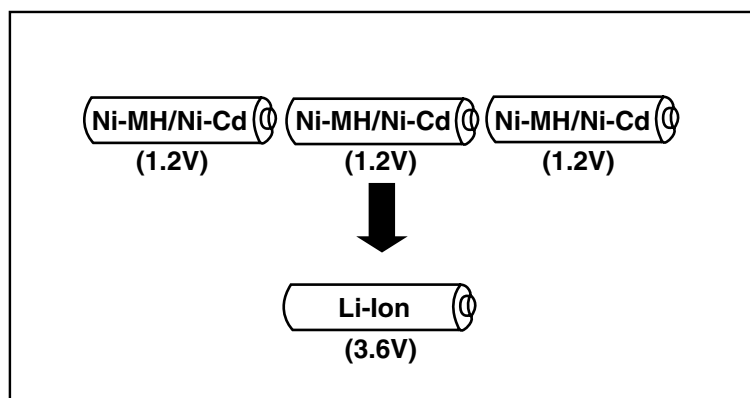
● High Energy Density

Because the lithium ion batteries are high voltage/light weight batteries, they boast a higher energy density than nickel metal hydride (Ni-MH) batteries or nickel cadmium (Ni-Cd) batteries.



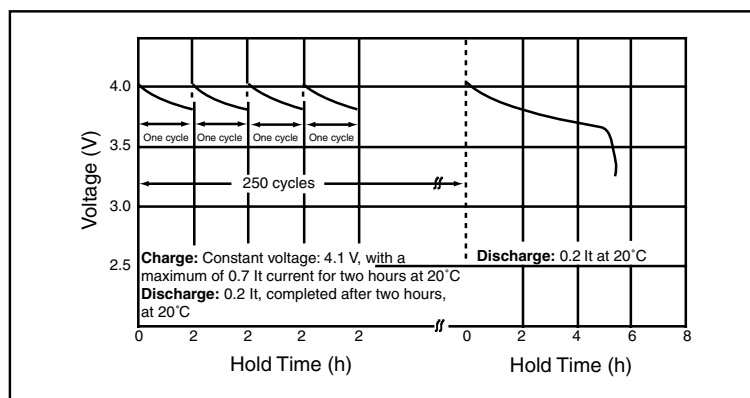
● High Voltage

Lithium ion batteries produce 3.6 volts, approximately three times the voltage of Ni-MH batteries or Ni-Cd batteries. This will make it possible to make smaller, lighter equipment.



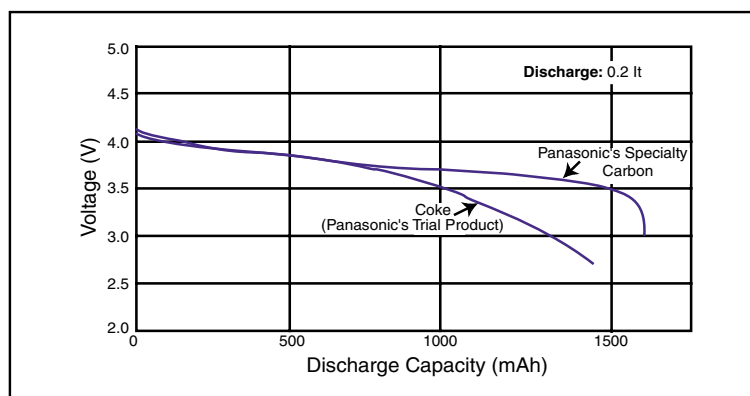
● No Memory Effect

Lithium ion batteries have none of the memory effects seen in Ni-Cd batteries ("memory effect" refers to the phenomenon where the apparent discharge capacity of a battery is reduced when it is repetitively discharged incompletely and then recharged).



● Flat Discharge Voltage

The use of the specialty carbon creates an extremely flat discharge voltage profile, allowing the production of stable power throughout the discharge period of the battery.



*The data in this document are for descriptive purposes only and are not intended to make or imply any guarantee or warranty.

Overcharge/Overdischarge/Overcurrent Safety Circuits

• The Functions of the Safety Circuits (typical functions)

The voltages listed below are typical values and are not guaranteed. The charge voltage varies according to model number.

1. The Overcharge Safety Function

The charge stops when the voltage per cell rises above 4.30 ± 0.05 V.
The charge restarts when the voltage per cell falls below 4.10 ± 0.05 V.

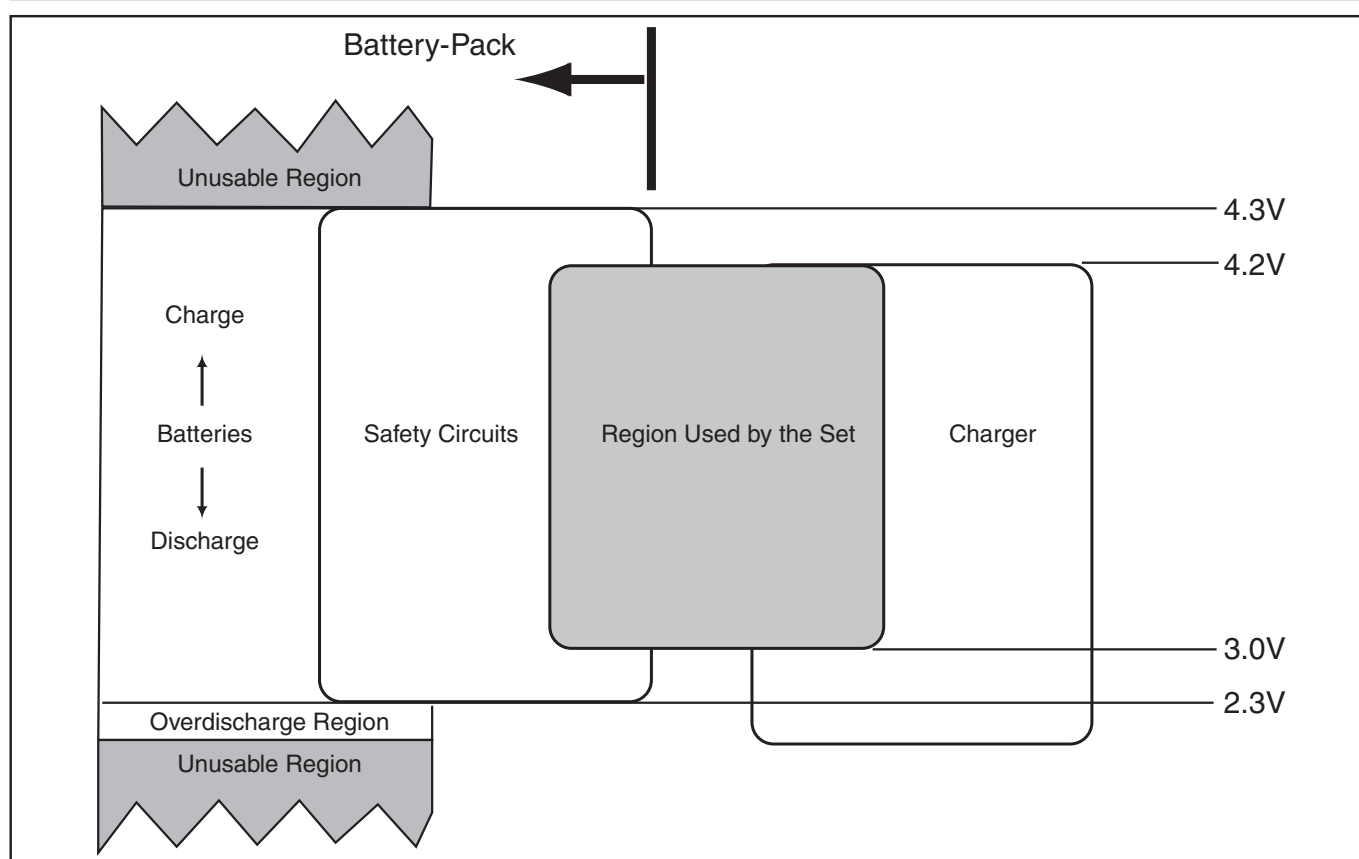
2. The Overdischarge Safety Function

The discharge stops when the voltage per cell falls below 2.3 ± 0.1 V.
The discharge restarts when the voltage per cell rises above 3.0 ± 0.1 V.
Contact Panasonic for information regarding NNP series.

3. The Overcurrent Safety Function

The discharge is stopped when the output terminals are shorted.
The discharge restarts when the short is removed.

• Reference Example of the Safety Circuits for PSS and Cobalt Acid Series



- The safety circuits in the diagram above are for overcharging, overdischarging, and overcurrent for a single cell battery-pack. Please consult Panasonic when two or more cells are connected or when actually using this or other circuits.

● **Battery-Pack Block Diagram (Reference Example)**

The diagram below shows a diagram of a lithium ion battery-pack. The battery-pack includes the batteries, the safety circuits, and thermistors.

1. The Safety Circuits

(1) The Controller IC

The controller IC measures the voltage for each cell (or for each parallel battery block) and shuts off a control switch to either prevent overcharging (if the voltage exceeds the specified voltage range) or to prevent overdischarging (if the voltage falls below the specified voltage range). Moreover, the voltage of the control switch is measured on both ends and in order to prevent overcurrent, control switches are shut off if the voltage exceeds specifications.

(2) The Control Switches

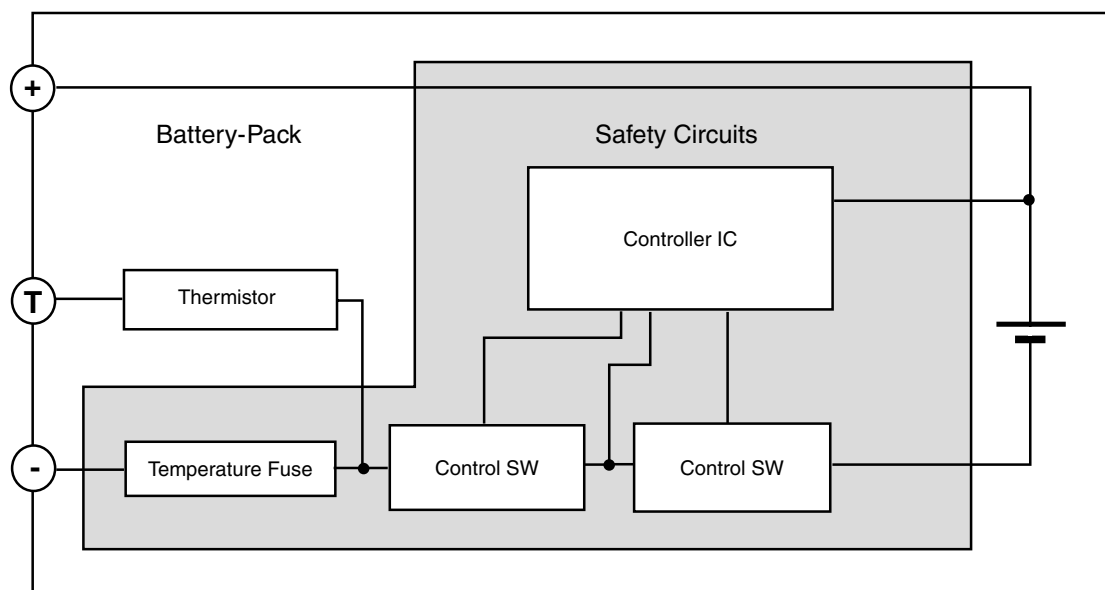
The control switches usually comprise FET structures, and they turn off the charge or discharge depending on the output of the controller IC.

(3) The Temperature Fuse (Reference Materials)

If the control switches experience abnormal heating, this fuse cuts off the current (non-restoring).

2. The Thermistors

The thermistors are included in order to accurately measure the battery temperature within the lithium ion battery-packs. The battery or charger measures the resistance value of the thermistor between the T-terminal and the negative terminal and during the charging process, controls the charge current along with controlling until the charge is terminated.



- The battery-pack must be equipped with a noise filter at the voltage detectors in the block diagram above to insure that outside noise does not cause the battery to malfunction. Please check against the final product
- Please include a total charge timer and a charge completion timer on the charging circuit in order to provide redundant safety control.

How to Charge the Batteries

We recommend the following charging process to insure the optimal performance of the lithium ion battery.

• Applicable Battery-Packs

The discussion below assumes that the battery-packs are equipped with internal safety circuits to prevent overcharging and overdischarging, and assumes that the battery is a single cell battery.

• Charging Method

The lithium ion battery can be charged by the constant voltage/constant current charging method found in the "Notes and Precautions" at the beginning of this document. (See page 22, "Notes and Precautions")

• Functions and Performance Required in the Charger (Recommendations)

(1) Charge Voltage

The voltage between the charging terminals should be no more than 4.20 V (Set this at 4.20 V (max) after taking into account fluctuations in power supply voltages, temperature deviations, etc.).

(2) Charge Current

Please refer to the following charge current standards by series.

NNP series Cylindrical type : 0.3 It , Prismatic type : 0.7 It.

PSS and Cobalt acid series Cylindrical type : 0.7 It , Prismatic type : 1.0 It. (or 0.7 It for certain models)

(3) Ambient Temperature of the Battery-Pack During Charge

0°C to 45°C (Consult Panasonic if the battery-pack is to be used outside of this temperature range).

(4) Low-Voltage Battery-Pack Charge

When the voltage per cell is 2.9 V or less, charge using a charge current of 0.1 It or less.

(5) Termination of Charging

The system will determine that the battery is full by detecting the charge current.

Stop charging once the current has reached 0.1 It to 0.07 It. Note that there will be some degree of variation for each individual battery.

(6) Charge Timer

A total charge timer and a charge completion timer should be included.

(7) Countermeasures for Battery Problems

Select an overvoltage guard in the power supply so that there will be no excessive voltage applied to the battery even if there is a problem with the power supply.

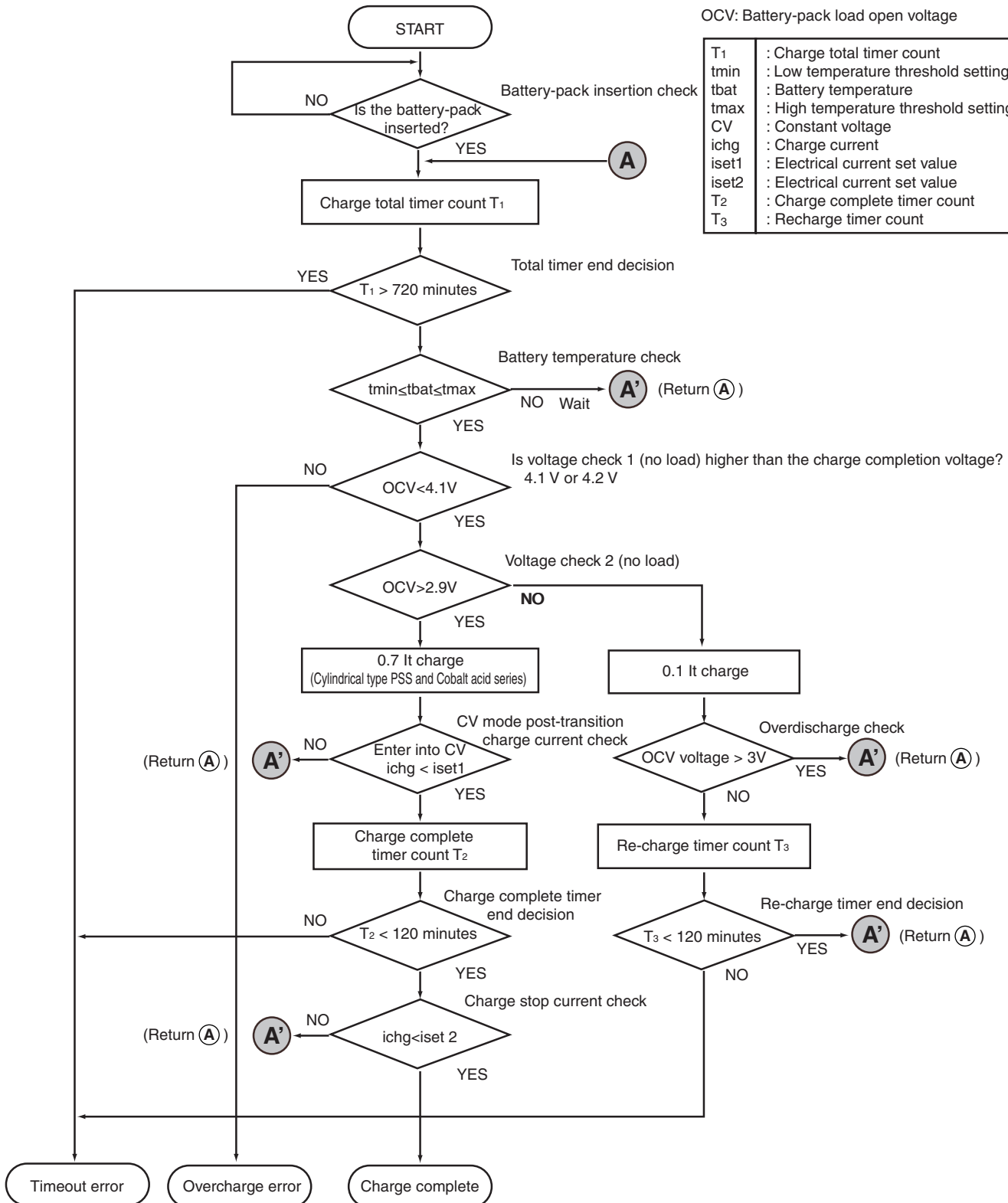
- The discussion above assumes a single cell battery. If two or more cells will be used or if there are other situations, please consult with Panasonic.

Lithium Ion Battery-Pack Charge Flowchart (example)

Reference example of charging a single-cell lithium ion battery-pack

OCV: Battery-pack load open voltage

T ₁	: Charge total timer count
t _{min}	: Low temperature threshold setting value
t _{bat}	: Battery temperature
t _{max}	: High temperature threshold setting value
CV	: Constant voltage
ichg	: Charge current
iset1	: Electrical current set value
iset2	: Electrical current set value
T ₂	: Charge complete timer count
T ₃	: Recharge timer count



Battery-Pack Specification Checklist

Battery-Pack Specification Checklist

Fill in the blanks below to determine specifications when making inquiries or when ordering batteries.

1. Battery-Pack: General

- 1) Schedule: (1) Completion of design evaluation: Month: ____ Year: ____
(2) Completion of mass production evaluation: Month: ____ Year: ____
(3) Start of delivery: Month: ____ Year: ____
- 2) Number of units: ____ k packs per month (Total volume: ____ k packs)
- 3) Delivery Destination: (1) Domestic (2) Overseas (Name of country: _____)
- 4) Operating Temperature: (1) Standard (where the standard is 0°C to 45°C)
(2) Custom (____ °C to ____ °C)
- 5) Ambient Humidity: (1) Standard (where standard is 45 to 85%, non-condensing)
(2) Custom (____ % to ____ %)
- 6) Special Conditions for Use: (1) No (2) Yes ((1) Automotive (2) Outdoors (3) Other (_____))
- 7) Applicable Specifications: (1) Electrical Appliance and Material Safety Law (2) UL (3) Other (_____)
- 8) Applicable Recipient: (1) Customer (2) Panasonic (3) Other (_____)
- 9) Application: (1) Portable telephone (2) AV equipment (_____)
(3) Personal computer (4) Other (_____)
- 10) FG (Fuel Gauge) (1) Required (2) Not required (if required, fill in item 3)

2. Battery-Pack Basic Specifications

- 1) Battery-Pack Configuration: (1) Hard case (2) Soft pack (3) Other (_____)
- 2) Battery-Pack Materials: Specify (_____)
- 3) Battery & Structure Used: Please see P.33-34
(____ P x ____ S)
- 4) Rated Capacity: ____ mAh
- 5) Charging Method: (1) Fast (2) Standard (3) Other (_____)
- 6) Charge Current: ____ A
- 7) Charge Time: ____ hours
- 8) Discharge Ending Voltage: ____ V
- 9) Thermistor: (1) Standard (Present/Absent) (Standard: 10 KΩ, 25°C) (2) Other (_____)
- 10) Drop Strength: (1) Present (____ cm) (2) Absent
- 11) Flame Retardants Requirements: (1) Present (____) (2) Absent
- 12) Dimensions: ____ width x ____ length x ____ height mm or less
- 13) Weight: ____ g or less
- 14) Label: (1) Not required (2) Required (Details of label specified elsewhere.)
- 15) Terminal Configuration: (_____)

3. Fuel Gauge Specifications

- 1) Range of load currents: (____ mA to ____ mA)
- 2) Load current waveform: (1) Wave height ____ mA (2) Conductive period ____ mSec
(3) Stop period ____ mSec
- 3) Accuracy: (1) ± 10% (2) ± 5% (3) Other (_____)
- 4) Display method: (1) LED (2) Communications
(3) LED and communications (communications method _____)
- 5) Mode change (1) Not required (2) Required (Modes (suspend, etc.) (1) ____ (2) _____)
- 6) Communications data: (1) Remainder (2) Voltage (3) Current (4) Temperature
(5) ID code (6) Other (_____)
- 7) Charge function (1) Not required (2) Required

Charger Specification Checklist

Charger Specification Checklist

Fill in the blanks below to determine specifications when making inquiries or when ordering.

1. General

- 1) Start of Delivery: Month: ____ Year: ____ Number of units: ____ per month
(Total volume: _____ units)
- 2) Delivery Destination: (1) Domestic (2) Overseas (Name of country: _____)
- 3) Operating Temperature: (1) Standard (where standard is 0°C to 45°C)
(2) Custom (____ °C to ____ °C)
- 4) Ambient Humidity: (1) Standard (where standard is 45 to 85%, non-condensing)
(2) Custom (____ % to ____ %)
- 5) Special Conditions for Use: (1) No (2) Yes ((1) Automotive (2) Outdoors (3) Other (_____))
- 6) Applicable Specifications: (1) Electrical Appliance and Material Safety Law (2) UL (3) Other (_____)
- 7) Applicable Recipient: (1) Customer (2) Panasonic (3) Other (_____)
- 8) Application: (1) Portable telephone (2) AV equipment (_____)
(3) Personal computer (4) Other (_____)

2. Basic Specifications

- 1) Battery-Pack Compatibility: Please see P.33-34
(____P x ____S)
- 2) Charging Method: (1) Fast (2) Standard (3) Other (_____)
- 3) Charge Current: ____A (Consult Panasonic regarding charging conditions.)
- 4) Charge Time: ____ hours
- 5) Charger Model: (1) Pocket type (2) 1 Unit (3) 2 Units (4) Other (_____)
- 6) Display LED: No. of Units: _____
- 7) Power Supply Voltage: ____ V/ ____ Hz (Range of Fluctuation: ____ V to ____ V/ ____ Hz to ____ Hz)
- 8) Drop strength: ____ cm
- 9) Dimensions: ____ width x ____ length x ____ height mm or less
- 10) Weight: ____ g or less
- 11) Label: (1) Not required (2) Required (Details of label _____)

Glossary of Terminology

Term	meaning
Average Capacity	The amount of energy which can be obtained from a cell under set temperature, discharge current and cut-off voltage conditions. Measured in Ampere hours (Ah), or mAh.
Battery Life Characteristics	Characteristics shown according to the time needed for each charge / discharge cycle when cycling charge / discharge under set conditions. Also referred to as "cycle characteristics".
Capacity	A battery's electric potential. Usually means capacity in ampere hours, indicated by Ah or mAh.
Capacity Recovery Ratio	Ratio of the maximum capacity obtained from a cell under set conditions that has been stored for a fixed period of time and charged a fixed number of times, over average capacity (assumed value of 100).
Capacity Retention Ratio	Ratio of cell capacity measured under set conditions after storage for a fixed period of time, over average capacity (assumed value of 100).
Charge Capacity	Amount of energy used in charging a battery. For constant current charging, it is the product of current and charge time. Measured units called Ampere hours (Ah).
Cut-off voltage	Voltage which expresses the limit to end discharge.
Electrolyte Leakage	When electrolyte fluid from inside the battery leaks to the battery's outer surface.
Energy Density	The amount of energy which can be obtained from a single cell by weight or by volume. Measured in units of Wh / kg or Wh / l.
It	Represents "Current" and is defined as follows $I_t(A) = \text{Rated Capacity (Ah)} / 1(h)$.
Large Current Discharge	Discharge with a relatively high current compared to the battery capacity. Also referred to as "high-rate" discharge.
Nominal Voltage	Voltage shown on the battery label.
Overcharge	Continued charging after the cell has reached a fully charged state. Overcharging a battery can adversely affect its safety and electrical characteristics.
Overdischarge	Continued discharge after cell voltage falls below the determined cut-off voltage.
Self-discharge	When battery capacity declines without current flowing to an outside circuit.
Unused Battery	An unused battery is defined as one produced less than 1 month ago, and has undergone less than 5 charge / discharge cycles.