**Meeting the Needs of Portable Electronic Devices:**

# Lithium Ion Batteries

## • Overview

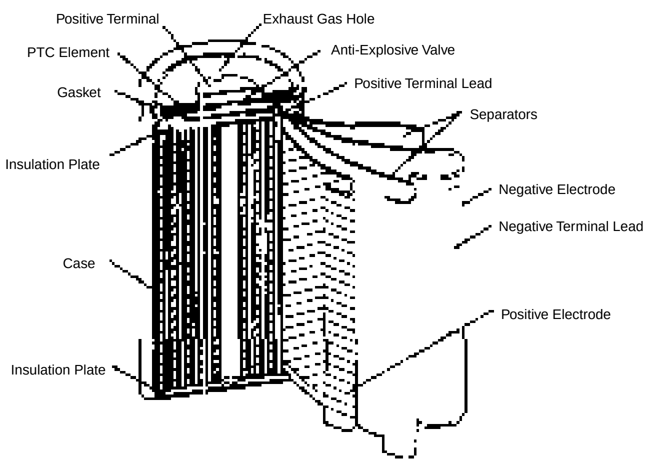
Panasonic lithium ion batteries, products of Panasonic's long experience with batteries and leading-edge battery technology, are excellent sources for high-energy power in a variety of portable devices, such as portable computers and cellular phones. Light weight and boasting high voltage ratings (3.6 V), these high-energy density batteries provide a variety of features that will contribute to the weight reduction and downsizing of portable products.

## • Structure

The lithium ion battery has a three-layer, coiled structure within its case. These three layers are comprised of a positive electrode plate (made with lithium cobalt oxide as its chief active ingredient), a negative electrode plate (made with a specialty carbon as its chief active ingredient), and a separator layer.

The battery is equipped with a variety of measures to insure safety, along with an anti-explosion valve that releases gas if the internal pressure exceeds a specific value, thereby preventing the battery from explodeing.

**The Structure of Lithium Ion Batteries (Cylindrical)**




## • Safety

Panasonic's lithium ion batteries (CGR17500, CGR17670HC, CGR17670HG, CGR18650HM, CGR18650HG, CGR18650B, CGP30486, CGP34506, CGP345010 and CGP345010G, CGA533048, CGA633450A and CGA103450,) have obtained UL1642 approval.

## • 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:

**Positive Electrode**

$$LiCoO_2 \xrightleftharpoons[\text{Discharge}]{\text{Charge}} Li_{1-x}CoO_2 + xLi^+ + xe^-$$

**Negative Electrode**

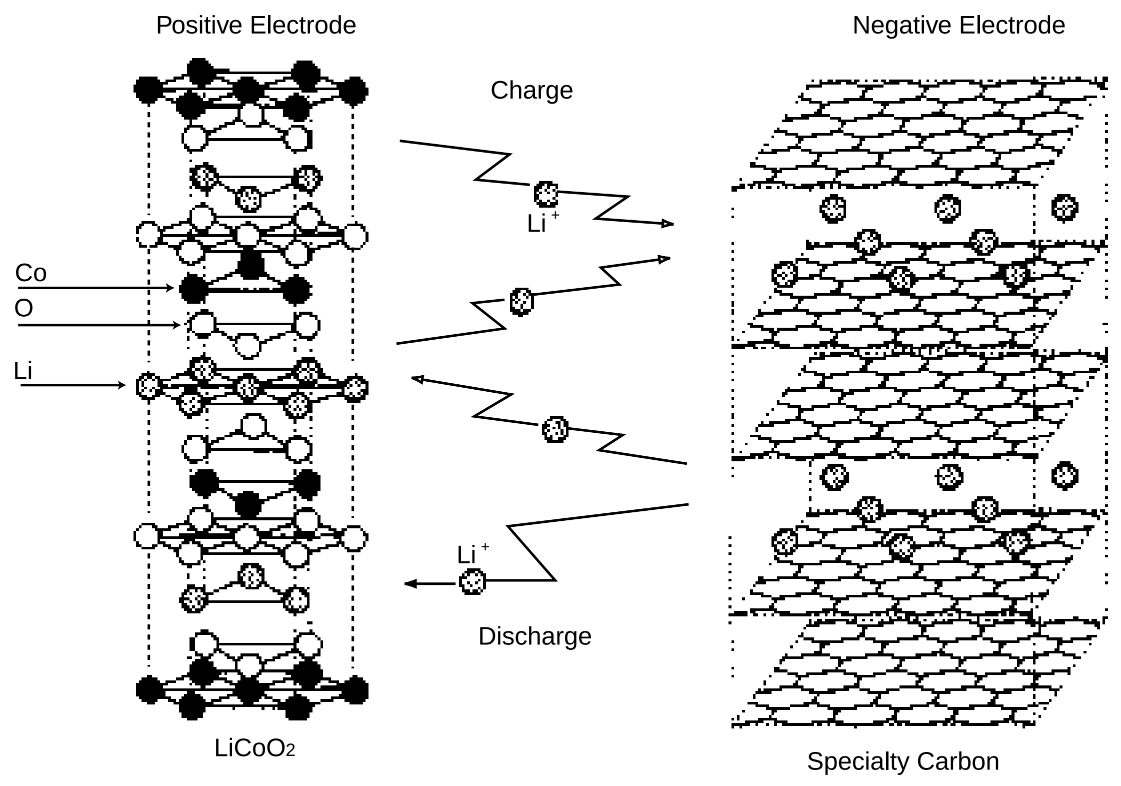
$$C + xLi^+ + xe^- \xrightleftharpoons[\text{Discharge}]{\text{Charge}} CLi_x$$

**Battery as a Whole**

$$LiCoO_2 + C \xrightleftharpoons[\text{Discharge}]{\text{Charge}} Li_{1-x}CoO_2 + CLi_x$$

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.

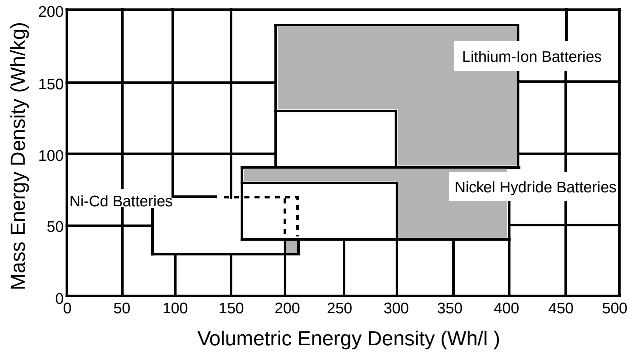
### Schematic Diagram of the Chemical Reaction of the Lithium Ion Battery



# FEATURES OF THE LITHIUM ION BATTERIES

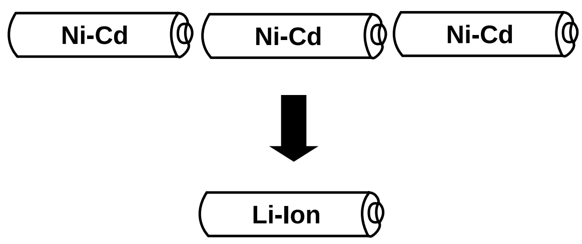
## • High Energy Density

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



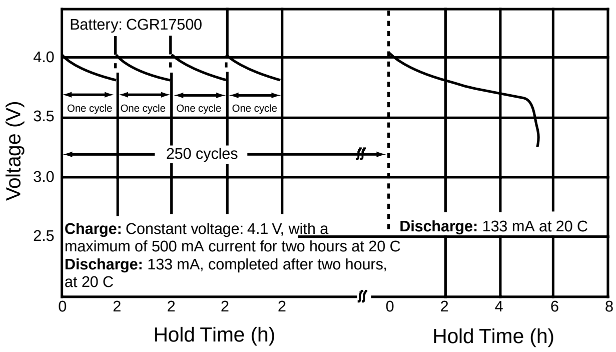

## • High Voltage

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



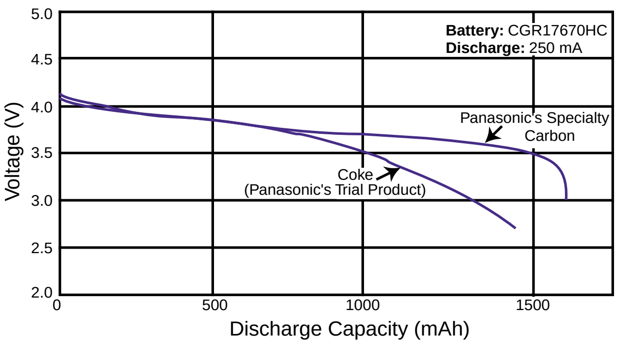

## • No Memory Effect

Lithium ion batteries have none of the memory effects seen in rechargeable 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.



# 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 4.00 ± 0.15 V.

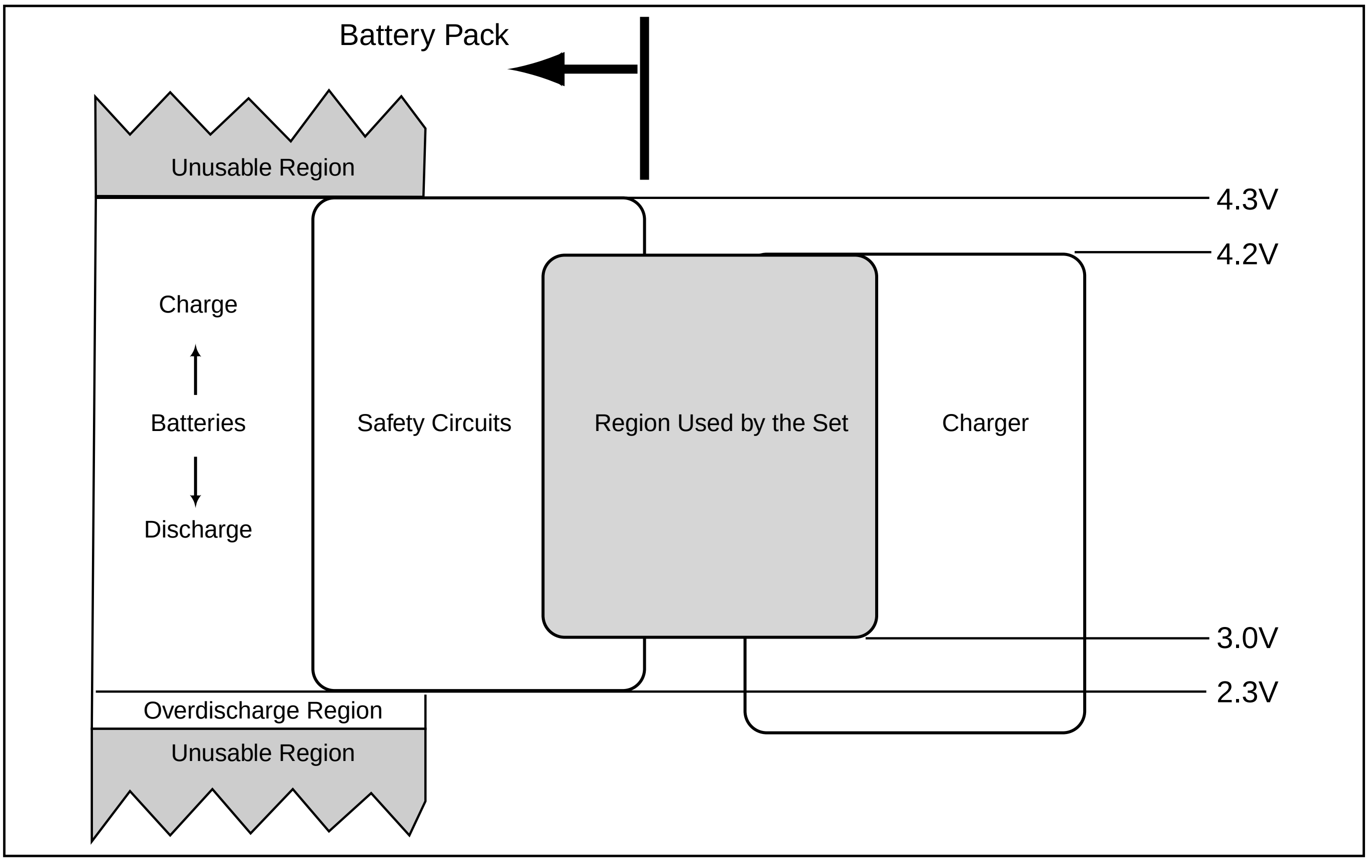
### 2. The Overdischarge Safety Function

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 ± 0.15 V.

### 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




- The safety circuits in the diagram above are for overcharging, overdischarging, and overcurrent for a single cell battery pack. Please contact 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

**1.1 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, both control switches are shut off if the voltage exceeds specifications.

**1.2 The Control Switches**

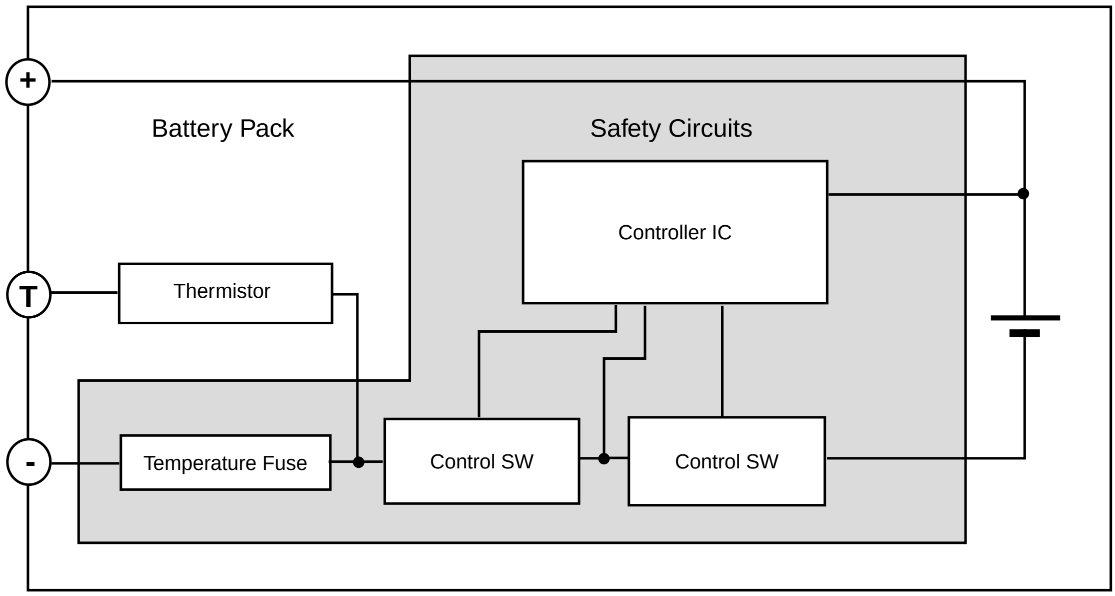
The control switches usually comprise FET structures, and they turn off the charge or discharge depending on the output of the controller IC.

**1.3 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 2, "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 4.20V (Set this at 4.20 V (max) after taking into account fluctuations in power supply voltages, temperature deviations,etc.).

**(2) Charge Current**

The reference charge current should be 0.7 ItmA.

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

0℃ to 45℃ (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 2.9V or less, charge using a charge current of 0.1 ItmA 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 ItmA to 0.07 ItmA. 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

| | |
|---|---|
| T1 | : Charge total timer count |
| tmin | : Low temperature threshold setting value |
| tbat | : Battery temperature |
| tmax | : High temperature threshold setting value |
| CV | : Constant voltage |
| ichg | : Charge current |
| iset1 | : Electrical current set value |
| iset2 | : Electrical current set value |
| T2 | : Charge complete timer count |
| T3 | : Recharge timer count |