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Panasonic

Nickel Cadmium Batteries Technical Handbook '02/'03

PDF File Technical Handbook

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.

Nickel Cadmium Batteries: Table of Contents

In order to take full advantage of the properties of Ni-Cd batteries and also to prevent problems due to improper use, please note the following points during the use and design of battery operated products.

Underlined sections indicate information that is especially important

1. Charging

1.1 Charging temperature

- Charge batteries within an ambient temperature range of 0°C to 45°C.
- Ambient temperature during charging affects charging efficiency. As charging efficiency is best within a temperature range of 10°C to 30°C, whenever possible place the charger (battery pack) in a location within this temperature range.
- At temperatures below 0°C the gas absorption reaction is not adequate, causing gas pressure inside the battery to rise, which can activate the safety vent and lead to leakage of alkaline gas and deterioration in battery performance.
- Charging efficiency drops at temperatures above 40°C. This can disrupt full charging and lead to deterioration in performance and battery leakage.

1.2 Parallel charging of batteries

- Sufficient care must be taken during the design of the charger when charging batteries connected in parallel.
  Consult Panasonic when parallel charging is required.

1.3 Reverse charging

- Never attempt reverse charging.
  Charging with polarity reversed can cause a reversal in battery polarity causing gas pressure inside the battery to rise, which can activate the safety vent, lead to alkaline electrolyte leakage, rapid deterioration in battery performance, battery swelling or battery rupture.

1.4 Overcharging

- Avoid overcharging. Repeated overcharging can lead to deterioration in battery performance. (“Overcharging” means charging a battery when it is already fully charged.)

1.5 Rapid Charging

- To charge batteries rapidly, use the specified charger (or charging method recommended by Panasonic) and follow the correct procedures.

1.6 Trickle charging (continuous charging)

- Carry out trickle charge by applying the current of 0.02 to 0.05 CmA. The correct current value is determined depending on the features and purpose of the equipment.
- Note : “CmA”
  During charging and discharging, CmA is a value indicating current and expressed as a multiple of nominal capacity. Substitute “C” with the battery’s nominal capacity when calculating. For example, for a I500mAh battery of 0.033CmA, this value is equal to 1/30 × 1500, or roughly 50mA.

2. Discharging

2.1 Discharge temperature

- Discharge batteries within an ambient temperature range of -20°C to +65°C.
- Discharge current level (i.e. the current at which a battery is discharged) affects discharging efficiency. Discharging efficiency is good within a current range of 0.1 CmA to 0.5 CmA.
- Discharge capacity drops at temperatures below -20°C or above +65°C. Such decreases in discharge capacity can lead to deterioration in battery performance.

2.2 Overdischarge

- Since overdischarging damages the battery characteristics, do not forget to turn off the switch when discharging, and do not leave the battery connected to the equipment for long periods of time. Also, avoid shipping the battery installed in the equipment.

2.3 High-current discharging

- As high-current discharging can lead to heat generation and decreased discharging efficiency, consult Panasonic before attempting continuous discharging or pulse discharging at currents larger than 2 CmA.

3. Storage

3.1 Storage temperature and humidity (short-term)

- Store batteries in a dry location with low humidity, no corrosive gases, and at a temperature range of -20°C to +45°C.
- Storing batteries in a location where humidity is extremely high or where temperatures fall below -20°C or rise above +45°C can lead to the rusting of metallic parts and battery leakage due to expansion or contraction in parts composed of organic materials.

3.2 Long-term storage (2 year, -20°C to +35°C)

- Because long-term storage can accelerate battery self-discharge and lead to the deactivation of reactants, locations where the temperature ranges between +10°C and +30°C are suitable for long-term storage.
- When charging for the first time after long-term storage, deactivation of reactants may lead to increased battery voltage and decreased battery capacity. Restore such batteries to original performance by repeating several cycles of charging and discharging.
- When storing batteries for more than 1 year, charge at least once a year to prevent leakage and deterioration in performance due to self-discharging. When using a rapid voltage detection type battery charger carry out charge and discharge at least once every 6 months.

4. Service Life of Batteries

4.1 Cycle life

- Batteries used under proper conditions of charging and discharging can be used 500 cycles or more.
  Significantly reduced service time in spite of proper charging means that the life of the battery has been exceeded.
  Also, at the end of service life, an unusual increase in internal resistance, or an internal short-circuit failure may occur. Chargers and charging circuits should therefore be designed to ensure safety in the event of heat generated upon battery failure at the end of service life.
  Please contact Panasonic if you have any questions.

4.2 Service life with long-term use

- Because batteries are chemical products involving internal chemical reactions, performance deteriorates not only with use but also during prolonged storage.
  Normally, a battery will last 3 to 5 years if used under proper conditions and not overcharged or overdischarged.
  However, failure to satisfy conditions concerning charging, discharging, temperature and other factors during actual use can lead to shortened life (or cycle life) damage to products and deterioration in performance due to leakage and shortened service life.

5. Design of Products Which Use Batteries

5.1 Connecting batteries and products

- Never solder a lead wire and other connecting materials directly to the battery, as doing so will damage the battery's internal safety vent, separator, and other parts made of organic materials.
  To connect a battery to a product, spot-weld a tab made of nickel or nickel-plated steel to the battery's terminal strip, then solder a lead wire to the tab.
  Perform soldering in as short a time as possible.
- Use caution in applying pressure to the terminals in cases where the battery pack can be separated from the equipment.
- When rapid charging using the voltage detection method with a large current (1It or more), or when leaving the battery installed in the equipment, be sure to follow connecting the precaution listed above. Even for other uses, if connecting the precaution listed above is used as much as possible, contact defects in the connection process can be reduced.

5.2 Material for terminals in products using the batteries

- Because small amounts of alkaline electrolyte can leak out from the battery seal during extended use or when the safety vent is activated during improper use, use a highly alkaline-resistant material for a product's contact terminals in order to avoid problems due to corrosion.

High Alkaline-resistant Metals	Low Alkaline-resistant Metals
Nickel, stainless steel, nickel-plated steel, etc.	Tin, aluminum, zinc, copper, brass, etc.

(Note that stainless steel generally results in higher contact resistance.)

5.3 Temperature related to the position of batteries in products

- Excessively high temperatures (i.e. higher than 45°C) can cause alkaline electrolyte to leak out from the battery, thus damaging the product and shorten battery life by causing deterioration in the separator or other battery parts. Install batteries far from heat-generating parts of product. The best battery position is a battery compartment that is composed of an alkaline-resistant material which isolates the batteries from the product's circuitry. This prevents damage caused by a slight leakage of alkaline electrolyte from the battery. Be careful particularly when trickle charging is carried out (for continuous charging).

5.4 Discharge end voltage

- Overdischarge and reverse charge of the battery deteriorate battery characteristics. This can be caused by several actions, such as forgetting to turn off the power. Installing an overdischarge cutoff circuit is recommended in order to avoid overdischarge and reverse charge.
- The discharge end voltage is determined by the formula given below.

Number of Batteries Arranged Serially	
1 to 6	(Number of batteries × 1.0) V
7 to 20	((Number of batteries - 1) × 1.2) V

5.5 Overdischarge (deep discharge) prevention

- Overdischarging (deep discharging) or reverse charging damages the battery characteristics. In order to prevent damage associated with forgetting to turn off the switch or leaving the battery in the equipment for extended periods, it is hoped that preventative options are incorporated in the equipment. At the same time, it is recommended that leakage current is minimized. Also, the battery should not be shipped inside the equipment.

6. Prohibited Items Regarding the Battery Handling

- Panasonic assumes no responsibility for problems resulting from batteries handled in the following manner.

6.1 Disassembly

- Never disassemble a battery, as the electrolyte inside is strong alkaline and can damage skin and clothes.

6.2 Short-circuiting

- Never attempt to short-circuit a battery. Doing so can damage the product and generate heat that can cause burns.

6.3 Throwing batteries into a fire or water

- Disposing of a battery in fire can cause the battery to rupture. Also avoid placing batteries in water, as this causes batteries to cease to function.

6.4 Soldering

- Never solder anything directly to a battery. This can destroy the safety features of the battery by damaging the safety vent inside the cap.

6.5 Inserting the batteries with their polarities reversed

- Never insert a battery with the positive and negative poles reversed, as this can cause the battery to swell or rupture.

6.6 Overcharging at high currents and reverse charging

- Never reverse charge or overcharge with high currents (i.e. higher than rated). Doing so causes rapid gas generation and increased gas pressure, thus causing batteries to swell or rupture.
- Charging with an unspecified charger or specified charger that has been modified can cause batteries to swell or rupture. Be sure to indicate this safety warning clearly in all operating instructions as a handling restriction for ensuring safety.

6.7 Installation in equipment (with an airtight battery compartment)

- Always avoid designing airtight battery compartments. In some cases, gases (oxygen, hydrogen) may be given off, and there is a danger of the batteries bursting or rupturing in the presence of a source of ignition_(sparks generated by a motor switch, etc.).

6.8 Use of batteries for other purposes

- Do not use a battery in an appliance or purpose for which it was not intended. Differences in specifications can damage the battery or appliance.

6.9 Short-circuiting of battery packs

- Special caution is required to prevent short-circuits. Care must be taken during the design of the battery pack shape to ensure batteries cannot be inserted in reverse. Also, caution must be given to certain structures or product terminal shapes which can make short-circuiting more likely.

6.10 Using old and new batteries together

- Avoid using old and new batteries together. Also avoid using these batteries with ordinary dry-cell batteries, Ni-MH batteries or with another manufacturer's batteries.
  Differences in various characteristic values, etc., can cause damage to batteries or the product.

7. Other Precautions

- Batteries should always be charged prior to use. Be sure to charge correctly.

8. Final Point to Bear in Mind

- In order to ensure safe battery use and to prolong the battery performance, please consult Panasonic regarding charge and discharge conditions for use and product design prior to the release of a battery-operated product.

Responding to the Technological Revolution with Consistent Reliability!

Overview

Rechargeable Ni-Cd batteries are one type of alkaline storage battery, which is classified as a secondary battery. Ni-Cd batteries use nickel hydroxide as the positive electrode, cadmium as the negative electrode, and an alkaline electrolyte. They are designated by IEC 285 as alkaline secondary cells and batteries "Sealed nickel-cadmium cylindrical rechargeable single cells". First invented by Jungner of Sweden in 1899, the basis for practical application of rechargeable Ni-Cd batteries was made possible about 50 years later by the development of the totally sealed cell by Neumann of France.

Ever since our development and practical application of rechargeable Ni-Cd batteries in 1961, for over 30 years Panasonic has continued to make innovations and improvements in order to meet the ever-increasing needs and demands of the market. As a result, our rechargeable Ni-Cd batteries are used for all types of applications throughout the world. Panasonic has also applied many original technological developments in our rechargeable Ni-Cd batteries, including the fabrication of the negative electrode by a pasted method, the fabrication of the positive electrode by a sintered method or by using a new foamed metal material, and the use of a new thin type separator, thus achieving ever-higher levels of reliability and performance. In particular, reflecting the needs of the market, our SM120 and SM80 Series were developed as a new High Capacity and Rapid Charge type, challenging the limits of Ni-Cd batteries to provide both rapid charge and approximately double the capacity of our standard type.

Because Ni-Cd batteries are made using the scarce natural resources of nickel and cadmium, Panasonic is making a positive effort for recycling them from the viewpoint of protecting the global environment and ensuring the efficient utilization of the earth's natural resources.

Giving top priority to meeting the needs of our customers, Panasonic will continue to develop new products for providing power to the devices that are so important to today's comfortable, enjoyable, and productive living.

Construction

Rechargeable Ni-Cd batteries are comprised of a positive electrode plate which uses nickel hydroxide as its main active material, a negative electrode plate which uses a cadmium compound as its main active material, a separator made of a thin non-woven fabric, an alkaline electrolyte, a metal case, a sealing plate provided with a self-sealing safety valve, and other components. The positive and negative electrode plates, isolated from each other by the separator, are rolled in a spiral shape inside the case and sealed by the sealing plate by means of an insulation gasket. In battery types which are designed for high-current discharge, such as the "P" Series, our unique collection system is used for the collectors of the positive and negative electrode plates. By making the side walls of the metal case thinner, it became possible for the battery to be lighter in weight and to have a larger internal volume than previous models.

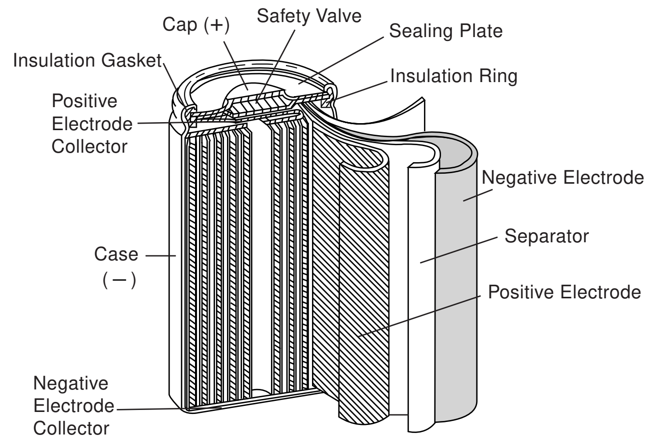


Figure 1 Construction

Battery Reactions

Generally, in rechargeable cells there are three different electro-chemical reactions: the discharge reaction which supplies electrical power to the load of the battery, the charge reaction which restores that electrical power, and the oxygen gas generation reaction resulting from the electrolysis of water on the positive electrode which occurs after the completion of charge, or, in other words, during overcharge. For rechargeable Ni-Cd batteries, the charge and discharge reactions are illustrated by the formula shown below.

The special characteristic of these reactions is that the alkaline electrolyte, for example, potassium hydroxide (KOH), does not apparently contribute directly to the reactions.

Positive Negative Discharge

$$2NiOOH + Cd + 2H_2O \rightleftharpoons 2Ni(OH)_2 + Cd(OH)_2$$

nickel oxyhydroxide | metal Cadmium | Water | Charge | Nickel hydroxide (1st) | Cadmium hydroxide

The battery is designed so that the capacity of the negative electrode is larger than that of the positive electrode, and the gas generated at the positive electrode is absorbed by reacting with the unreacted part of the negative electrode, thus making it possible for the battery to be completely sealed. In this design, the reactions become as follows.

$$\text{Positive} \quad 2OH^- \longrightarrow \tfrac{1}{2}O_2 + H_2O + 2e^-$$

$$\text{Negative} \quad Cd + \tfrac{1}{2}O_2 + H_2O \longrightarrow Cd(OH)_2$$

$$Cd(OH)_2 + 2e^- \longrightarrow Cd + 2OH^-$$

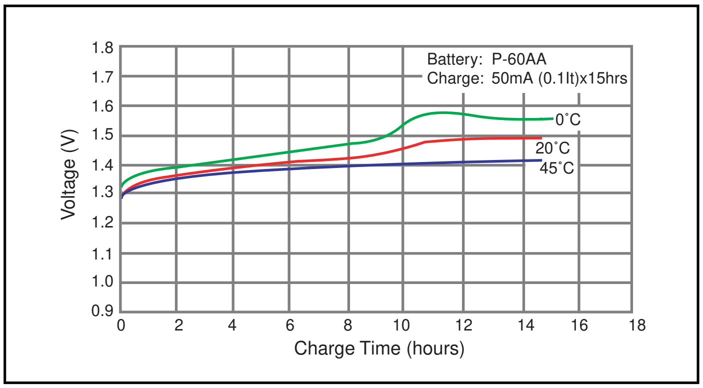
Five Main Characteristics of Ni-Cd Batteries

Ni-Cd batteries have five main characteristics: charge, discharge, cycle life, storage, and safety.

1. Charge Characteristics

The charge characteristics of Ni-Cd batteries are affected by the current, time, temperature, and other factors. Increasing the charge current and lowering the charge temperature causes the battery voltage to rise. Charge generates heat, thus causing the battery temperature to rise. Charge efficiency will also vary according to the current, time, and temperature. For rapid charge, a charge control system is required; refer to the following section on the charge methods for Ni-Cd batteries.

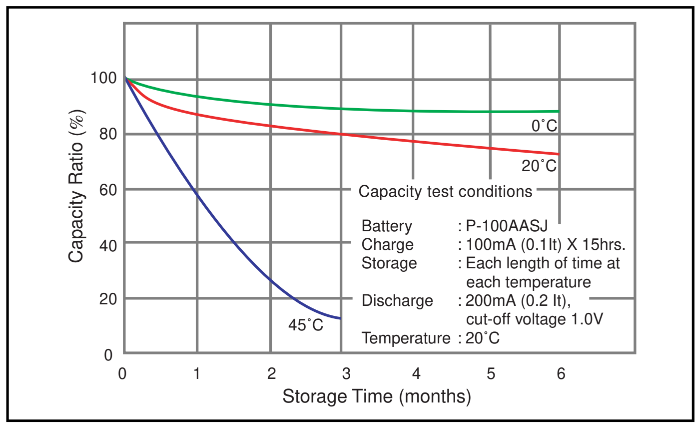
Typical Charge Characteristics



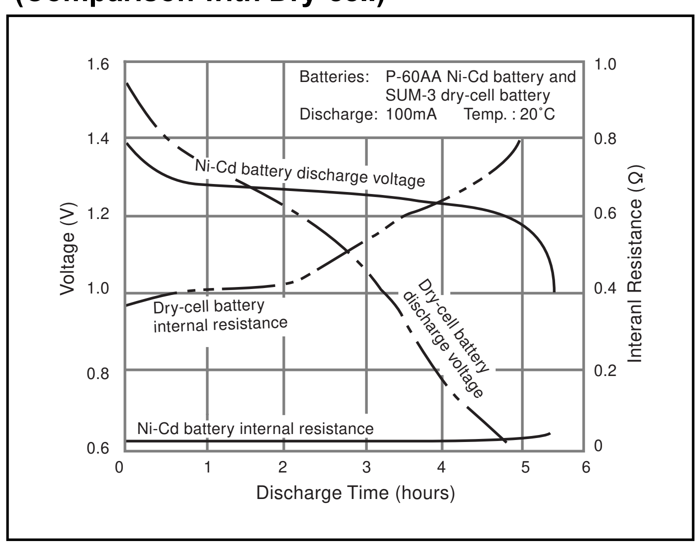
2. Discharge Characteristics

The discharge characteristics of Ni-Cd batteries will vary according to the current, temperature, and other factors. Generally, in comparison with dry-cell batteries, there is less voltage fluctuation during discharge, and even if the discharge current is high, there is very little drop in capacity. Among the various types of Ni-Cd batteries, there are models such as Panasonic's "P" type which are specifically designed to meet the need for high-current discharge, such as for power tools, and there are also models such as our new High Capacity and Rapid Charge type which are designed to meet the need for high capacity, such as for high-tech devices.

Typical Self-discharge Characteristics



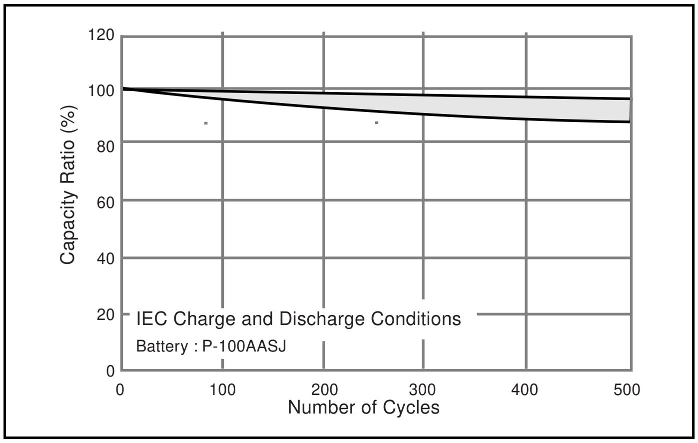
Typical Discharge Characteristics (Comparison with Dry-cell)



3. Cycle Life Characteristics

The cycle life of Ni-Cd batteries will vary according to the charge and discharge conditions, the temperature, and other usage conditions. When used in accordance with the IEC charge and discharge specifications, over 500 charge/discharge cycles are possible. The actual cycle life will vary according to which of the various charge formats is used, such as for rapid charge, and also according to how the device powered by the batteries is actually used.

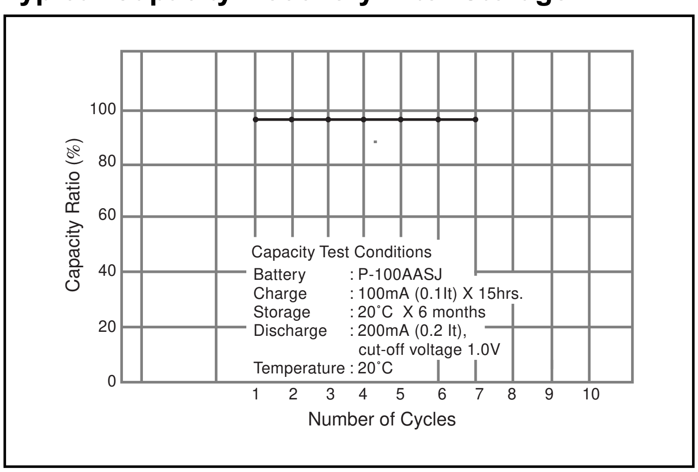
Typical Cycle Life Characteristics



4. Storage Characteristics

When Ni-Cd batteries are stored in a charged state, the capacity will gradually decrease (self discharge), and this tendency will be markedly greater at high temperatures. However, the capacity can be subsequently restored by charge. Even if the batteries are stored for an extended length of time, if the storage conditions are appropriate, the capacity will be restored by subsequent charge and discharge.

Typical Capacity Recovery After Storage



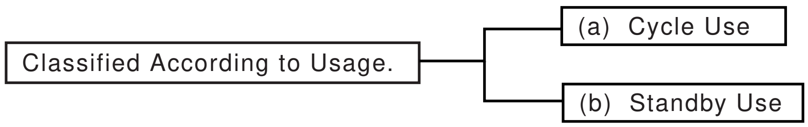
5. Safety

If pressure inside the battery rises as a result of improper use, such as overcharge, short-circuit, or reverse charge, a resetable safety valve will function to release the pressure, thus preventing bursting of the battery.

CHARGE METHODS FOR NI-CD BATTERIES

If the charge conditions are not appropriate, not only will the batteries not display their full performance potential, but the cycle life could also be shortened, and in extreme cases, electrolyte leakage could damage the device in which the batteries are used. Therefore, carefully select the appropriate charge method, taking into consideration the type of battery, the state of discharge, the charge current, and the ambient temperature.

The charge methods for Ni-Cd batteries can be generally classified into two types according to the purpose for which the batteries are used: cycle use and standby use.

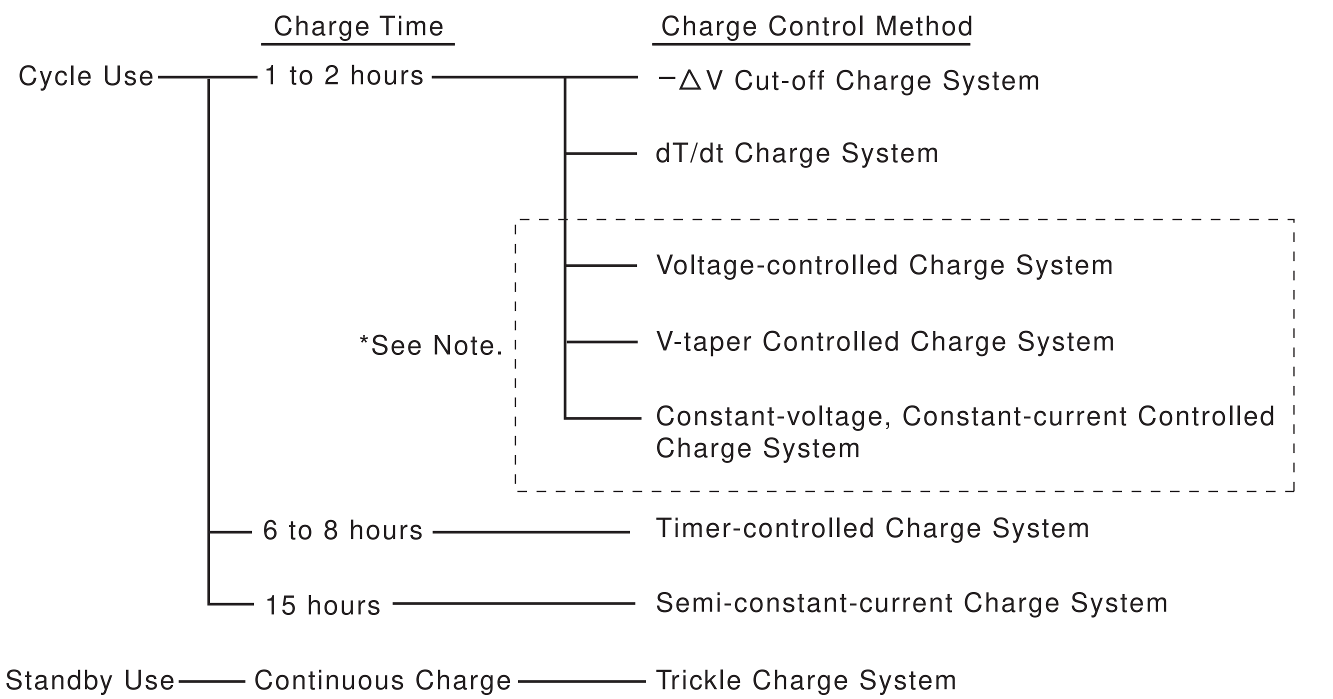


(a) Cycle Use
The battery is repeatedly charged and discharged. This is the most common method for using Ni-Cd batteries.

(b) Standby Use
Power is normally supplied to the load from an AC power supply, and the Ni-Cd battery is used to maintain the power supply to the load in the event that the AC power supply is interrupted.

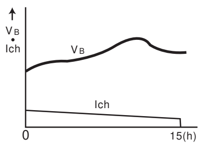
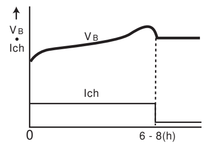
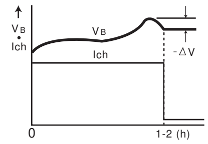
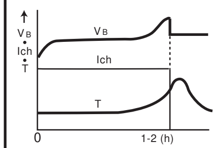
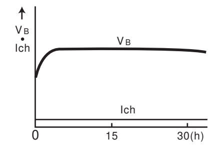
(1) Methods of Charge for Ni-Cd Battery

The methods of charge for Ni-Cd batteries can be classified as follows according to the purpose of use and the charge time.



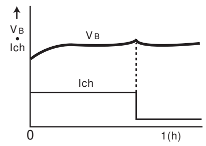
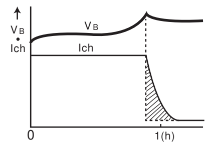
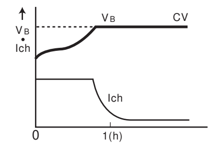
* Not a recommended charge method for Ni-Cd batteries

(2) General Comparison of the Various Charge Systems

Charge System	Cycle (Repeated) Use				Standby Use
	Semi-constant Current Charge	Timer Controlled Charge	- Δ V Cut-off Charge	dT/dt Cut off Charge	Trickle Charge
Operation VB: Battery Voltage Ich: Charge Current T: Battery Temperature					
Features	* Most typical charge system * Simple and economical	* More reliable than Semi-constant current charge system * Relatively simple and economical	* Most popular	* Charging circuit costs more than the others but overcharge can be avoided enabling longer life cycle than - Δ V charge method	* Simple and economical * Applicable to the equipment for continuous long charge
No. of Output Terminals	2	2	2	3	2
Charge Time	15 hours	6 to 8 hours	1 to 2 hours	1 to 2 hours	30 hours or longer
Charge Current	0.1 CmA	0.2 CmA	0.5 to 1 CmA	0.5 to 1 CmA	* frequent charge:0.05-0.033 CmA * less frequent charge: 0.033-0.02 CmA
Trickel Current	---	0.05-0.033 CmA	0.05-0.033 CmA	0.05-0.033 CmA	
Charge Level at Charge Control	---	approx. 120%	approx. 110 to 120%	approx. 100 to 110%	---
"N" (Standard) Type	⊗	O	---	---	---
"S" Type	---	---	⊗	O	---
"R" Type	O	O	⊗	O	---
"P" Type	O	O	⊗	⊗	---
"H" Type	---	---	---	---	⊗
"K" Type	---	---	---	---	⊗
Application Examples	* Shavers * Digital cordless phones * Toys	* Cordless Phone * Shavers	* Data Terminals * Camcorder * Wireless equipment * Cellular phones	* Power Tools * Electric Tools * Notebook PC * Cellular Phones	* Emergency lights * Guide lights * Memory back-up

⊗: Most recommended
O: Acceptable

(2) General Comparison of the Various Charge Systems - Continued

Charge System	For Reference Only (Not Recommended for the Main Charge Control System for Ni-Cd Batteries.)		
	Voltage Controlled Charge System	**V-taper Controlled Charge System**	**Constant-voltage, Constant-current Controlled Charge System**
Operation VB: Battery Voltage Ich: Charge Current T: Battery Temperature CV: Constant Voltage			
Features	* Not recommended for the main charge control system for Ni-Cd batteries.	* Not recommended for the main charge control system for Ni-Cd batteries. * Recommended charge control system for sealed lead acid batteries.	* Not recommended for the main charge control system for Ni-Cd batteries.
No. of Output Terminals	---	---	---
Charge Time	---	---	---
Charge Current	---	---	---
Trickel Current	---	---	---
Charge Level at Charge Control	---	---	---
"N" (Standard) Type	---	---	---
"S" Type	---	---	---
"R" Type	---	---	---
"P" Type	---	---	---
"H" Type	---	---	---
"K" Type	---	Basic charge control system for sealed lead acid batteries.	
Application Examples	---	---	

(3) Details of Each Charge Method

Semi-constant-current Charge System

(1) Mechanism

(A) Mechanism

A resistance is positioned between the DC power supply and the battery, thus stabilizing the charge current. By keeping the charge current low enough that the battery does not generate any heat, this method performs charge without using any control.

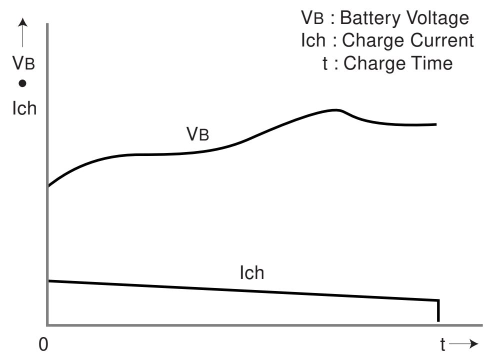


Fig. 1 Charge Characteristics of the Semi-constant-current Charge System

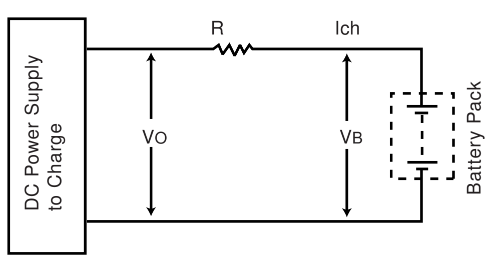


Fig. 2 Circuit Block Diagram of the Semi-constant-current Charge-system

(B) Calculation Example

The calculation formula for the block diagram of the semi-constant-current charge system shown in Fig. 1 is as follows.

V_o = Output voltage of the DC power supply for charge

V_c = Single-cell battery voltage (1.45 V/cell: average battery voltage during charge at 20°C, 0.1 CmA)

N = Number of cells used

V_B = Battery voltage (V_c x N)

R = Charge current stabilizing resistance

Ich = Charge current

$$Ich = \frac{V_o - V_B}{R} = \frac{V_C \times N \times (K) - V_C \times N}{R}$$

(K) is the stabilizing constant and must be selected in accordance with the purpose of the device in which the battery pack is used.

(2) Features

- The standard charge method for Ni-Cd batteries.
- The charger construction is simple and inexpensive.

(3) General Specifications

	Typical General Specifications
Number of Charger Output Terminals	2
Charge Current	0.1CmA
Charge Time	15 hours
Applicable Battery Types	N R P

(4) Cautions

- If the specific conditions of the device require that a charge rate higher than 0.1 CmA be used, the overcharge performance and temperature rise characteristics will vary according to the battery type. Consult Panasonic for further details and specifications.
- If a large number of battery cells are used, or if batteries having a high nominal capacity are used, or if the heat dissipation of the battery pack is poor, the batteries may generate heat even when charged at 0.1 CmA. In such cases, it is necessary to re-design the construction for better heat dissipation or to lower the charge current. Design so that the battery temperature rise at saturation is no higher than 50°C.
- The value of the above-mentioned stabilizing constant (K) must be selected carefully. If the value of K is too small, the fluctuation of the charge current with respect to the fluctuation of the power supply voltage will increase, and this could cause insufficient charge or overcharge.

- When the batteries reach the end of their cycle life, the usage time will become markedly shorter, and eventually two malfunction modes will occur: an internal short-circuit and the exhaustion of the electrolyte (the internal resistance will increase). Therefore, when designing the charger and the charge circuit, these malfunction modes (output short-circuit, etc.) at the end of the cycle life must be taken into consideration. Special care is required regarding the rated load of the charge current stabilizing resistance R so that an overload does not occur at the time of these battery malfunction modes.

Timer-controlled Charge System

(1) Mechanism

At the start of charge, an IC timer is started (counts up), and charge is continued at a current of 0.2 CmA for a specified time until the timer stops. After the timer stops, trickle charge continues at 0.05 CmA.

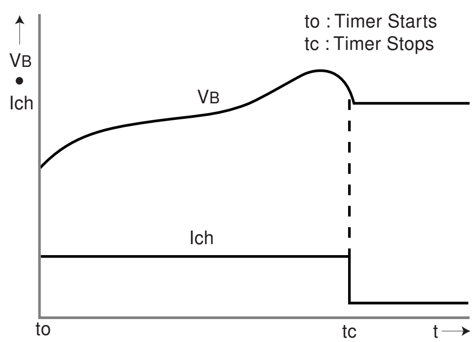


Fig. 3 Charge Characteristics of the Timer-controlled Charge System

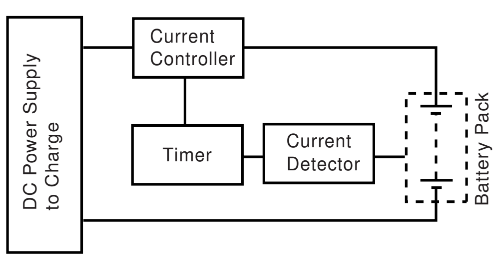


Fig. 4 Circuit Block Diagram of the Timer-controlled Charge System

(2) Features

- Compared with the semi-constant-current charge system (non-controlled), the addition of a charge timer improves the long-term reliability of charge.
- The construction of the charge circuit is relatively simple and inexpensive.

General Specifications

	Typical General Specifications
Number of Charger Output Terminals	2
Charge Current	0.2CmA
Charge Time	6 hours
Charge Level Until Timer Stops	120%
Trickle	Charge Current 0.05CmA
Applicable Battery Types	N S R P

(3) Cautions

- This method is not appropriate for applications in which the timer is frequently reset (charge is restarted).
- If frequent resetting of the timer is required, or if the specific conditions of the device require that a charge rate higher than 0.2 CmA be used (for example, timer-controlled charge at 0.3 CmA), it is necessary to combine this method with an absolute temperature cut-off charge system.
- The overcharge performance will vary according to the battery type.

- Δ V Cut-off Charge System

(1) Mechanism

If rapid charge Ni-Cd batteries are charged at a constant current, the battery voltage will increase as charge progresses, peak when charge is completed, and then subsequently decrease. Because this voltage drop occurs regardless of the discharge level or ambient temperature, it can be effectively used to detect the completion of charge. The -ΔV cut-off charge system controls charge by detecting the voltage drop (-ΔV) following the peak.

(2) Features

- The most common control method for rapid charge.
- The most recommended and widely used method for the rapid charge of Ni-Cd batteries for use in high-tech devices (for example, portable VCR, notebook PC, digital cordless and cellular phones, etc.).

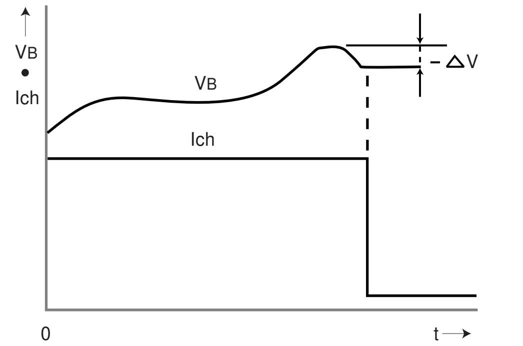


Fig. 5 Charge Characteristics of the -ΔV Cut-off Charge System

(3) General Specifications

	Typical General Specifications	Remarks
Number of Charger Output Terminals	2	
Charge Current	0.5 to 1.0 CmA	See (5) in Fig. 6.
Charge Time	1 to 2 hours	
Charge Level at -ΔV Cut-off	approx. 110 to 120%	
Trickle Charge Current	0.05CmA	See (6) In Fig. 6.
-ΔV Value	15 to 20 mV/cell	See (3) in Fig. 6.
Charge Mode Switching (1) (From Rapid Charge to Trickle Charge)	1.95 V/cell	See (2) in Fig. 6.
Charge Mode Switching (2) (From Initial Charge to Rapid Charge)	0.8 to 1.0 V/cell	See (4) in Fig. 6.
Initial Charge Current	approx. 0.2 CmA	See (7) in Fig. 6.
Total Timer Time	Time corresponding to a 150% charge level of the nominal capacity at the rapid charge current	See (8) in Fig. 6.
Initial Delay Timer	approx. 5 min.	See (1) in Fig. 6.
Safety Device	Thermal protector (included in the battery pack)	See Fig. 7 and 8.
Applicable Battery Types	S R P	

(3) Precautions

- This method is suitable for rapid charge Ni-Cd batteries.
- The charge current should be 0.5 CmA ~ 1 CmA. If charged at less than 0.5 CmA, the voltage drop after the peak voltage is reached might be too small for the -ΔV cut-off to function, resulting in overcharge. The maximum charge current will vary according to the specific type of battery, so it is important to select the appropriate charge current. (See (5) in Fig. 6)
- A constant-current power supply circuit is required. If fluctuations in the charge current occur as a result of fluctuations in the power supply voltage, the charge voltage will change, and faulty operation (stopping of charge before completion) of the charger might occur.
- The voltage detector shown in the block diagram must be provided with a noise canceller in order to prevent external noise from causing faulty operation (stopping of charge before completion) of the charger.
- An initial delay timer is needed in order to prevent faulty operation (stopping of charge before completion) of the charger from being caused by any false -ΔV phenomenon at the beginning of charge.
  False -ΔV phenomenon: When Ni-Cd batteries are left unused for a long period of time or excessively discharged, the charge voltage (false -ΔV*)* may swing at the beginning of charge. (See (1) in Fig 6)
  Initial delay timer: Prevents the -ΔV detection circuit from functioning for a certain length of time after rapid charge is begun.
- Be sure that the -ΔV value is correct. If it is not, faulty operation (overcharge or insufficient charge) of the charger might occur. (See (1) in Fig. 6)
- A voltage detection switch must be provided in order to change from the rapid-charge current to the trickle charge current when the charge voltage reaches the predetermined level.
  This predetermined level varies according to the type of battery, so consult Panasonic for the specific level. The trickle charge current should be 0.05 CmA. (See (2) and (6) in Fig. 6)
- If a voltage detection switch is provided in order to switch the charger to the rapid charge mode, set the voltage value to 0.8 to 1.0 V/cell. In addition, for the period of initial charge (before the start of rapid charge) until the battery voltage reaches the predetermined level, set the charge current to approximately 0.2 CmA. (See (5) and (7) in Fig. 6)
- Provide a total timer in the charge circuit as a double-safety control. (See (8) in Fig. 6)
- A thermal protector (thermostat) and other safety devices are needed inside the battery pack to ensure the safety of rapid charge. (See Figs. 7 and 8.)
- Especially for devices where charge is frequently performed at high temperatures or low temperatures (for example, chargers designed to be used in an automobile), in order to increase charge reliability, the charger is provided with a function that detects the temperature of the batteries and switches to trickle charge if the temperature is not within the specified range for rapid charge. Therefore, a thermistor or other temperature-detecting element must be provided inside the battery pack, and the battery pack will have a 3-terminal construction. (See (9) in Fig. 6 and Fig. 7)

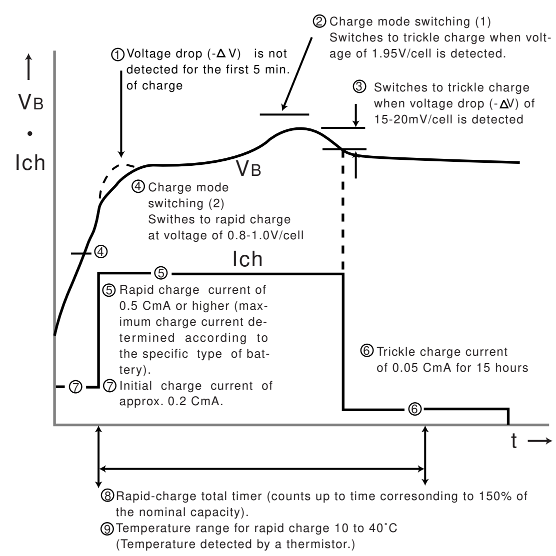


Fig. 6 Typical -ΔV Cut-off Charge System

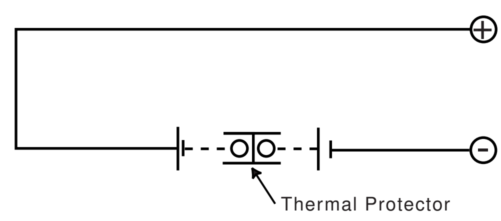


Fig. 7 Basic Battery Pack Circuit

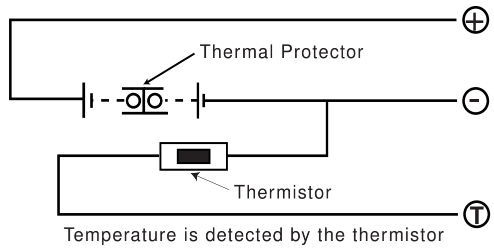


Fig. 8 Battery Pack Circuit for Low-temperature or High-temperature Charge

Trickle Charge System

There are generally two types of uses for trickle charge; As a standby power supply for devices such as emergency lights, and for additional charge following rapid charge. When used as a standby power supply, the appropriate charge current varies according to the frequency of discharge.

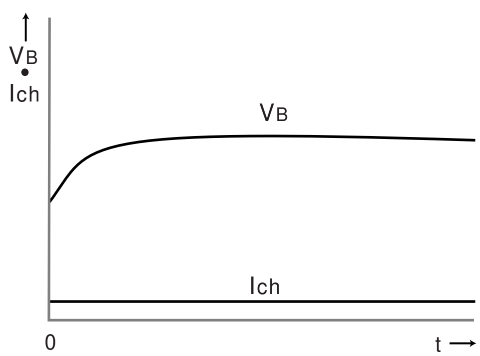


Fig. 9 Charge Characteristics of the Trickle Charge System

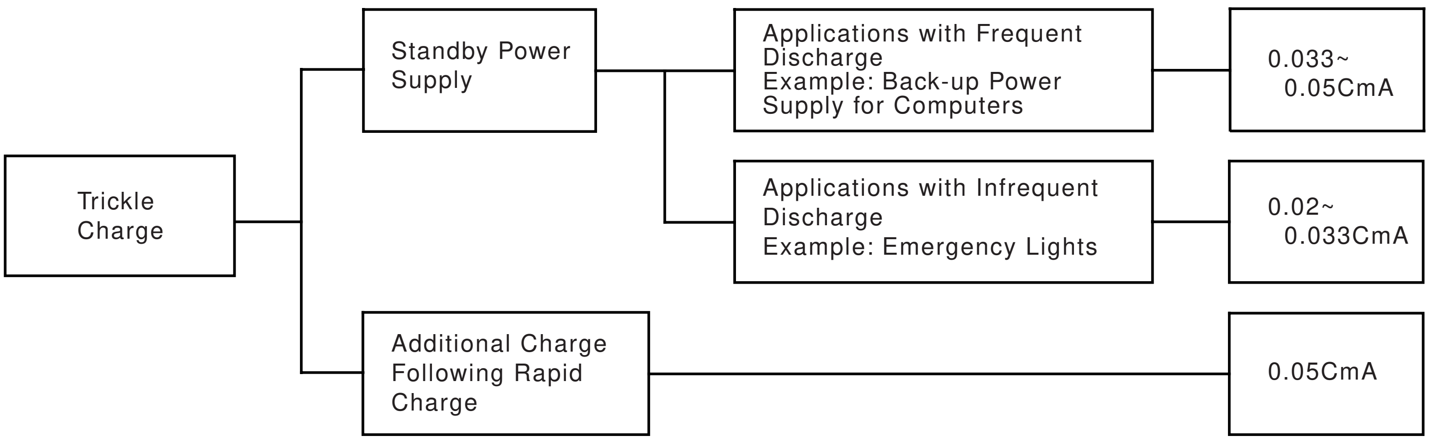
(1) Mechanism

While the AC power is being supplied, the battery is disconnected from the load and is charged by a very small current which only replenishes the self-discharge of the battery. Only in the event of an interruption in the AC power supply does power flow from the battery to the load.

(2) Features

- Mainly used as a standby power supply for emergency lights and other disaster-prevention equipment.
- The main purpose of trickle charge is to replenish the self-discharge of the battery, using a very small charge current of 0.02 to 0.05 CmA.
  It takes many hours to completely charge.

(3) General Specifications (Trickle Charge Current)



(4) Precautions

- The trickle charge current for use as a standby power supply should be set to a level at which charge will be completed by time of the next discharge, taking into consideration the frequency of discharge and the discharge current.
- If recovery charge at a relatively large current (for example, 0.1 CmA) is required, combine trickle charge with some other suitable charge control system (for example, timer-control charge).

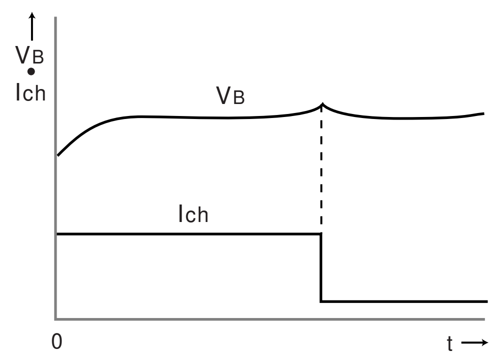


Fig. 10 Charge Characteristics of the Voltage-controlled Charge System

Voltage-controlled Charge System (for Reference Only)

(1) Mechanism

The charge voltage at the completion of charge is detected (the detection voltage can be freely set) by a voltage detection circuit inside the charger, and the charger switches from rapid charge to trickle charge. To compensate for temperature-related fluctuations in the charge voltage of Ni-Cd batteries, temperature compensation is added to the detection voltage.

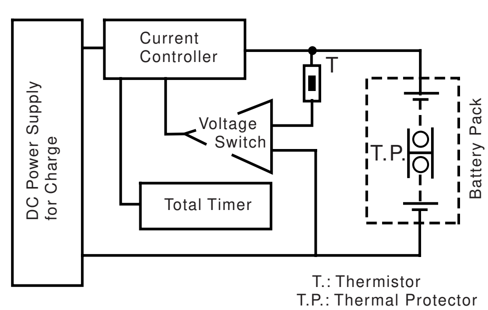


Fig. 11 Circuit Block Diagram of the Voltage-controlled Charge System

(2) Features

This method is rarely used today, and it is not appropriate for the charge control system for Ni-Cd batteries.

Matching the charger to the batteries is extremely difficult, and if the detection voltage of the charger is not set correctly, insufficient charge or overcharge (thermal runaway) can easily occur.

General Specifications

	Typical General Specifications
Number of Charger Output Terminals	2
Charge Current	0.5~1.0 CmA
Charge Time	1 to 2 hours (complete charge is difficult even with a longer charge time)
Charge Level at Voltage Control	Approx. 70%
Trickle Charge Current	0.05 CmA
Detection Voltage	(Detection voltage must be compensated for the temperature.)
Safety Device	Thermal protector + total timer
Applicable Battery Types	(Not recommended for use as the main charge control system for Ni-Cd batteries.)

(3) Precautions

- The setting of the detection voltage is extremely difficult. The setting of the detection voltage and of the temperature compensation must be done carefully, taking into consideration the variations and fluctuations of the batteries and of the charger as indicated below, and in order to avoid overcharge (thermal runaway), the detection voltage is generally set for insufficient charge.
  Batteries: Single-cell and multi-cell (battery pack) variations in the charge voltage, and fluctuation of the charge voltage caused by the ambient temperature.
  Charger: Variations in the adjustment of the set detection voltage, and fluctuation of the detection voltage caused by the ambient temperature.
- The charge voltage increases in batteries which have been left unused for a long period of time, and during charge the charge voltage will quickly reach the charger's detection voltage. Therefore, if the voltage-controlled charge control system is used to charge batteries which have not been used for a long period of time, the charge level will be low. Matching the charger to the batteries is extremely difficult, and if the detection voltage of the charger is not set correctly, insufficient charge or overcharge (thermal runaway) can easily occur. Therefore, this method should never be used as the main charge control system for Ni-Cd batteries.

V-taper Controlled Charge System

This is the charge control method recommended for Sealed Lead Acid batteries, and it is not recommended for charge Ni-Cd batteries.

(1) Mechanism

This system is basically the same as the voltage-controlled charge system already described. However, in the V-taper controlled charge system, after the set voltage is detected at the completion of charge, the rapid charge current is supplied as a tapered current, decreased at a predetermined rate over a predetermined length of time, and then switched to trickle current. Supplying the decreasing taper current makes it possible to achieve a higher charge level than with the voltage-controlled charge system.

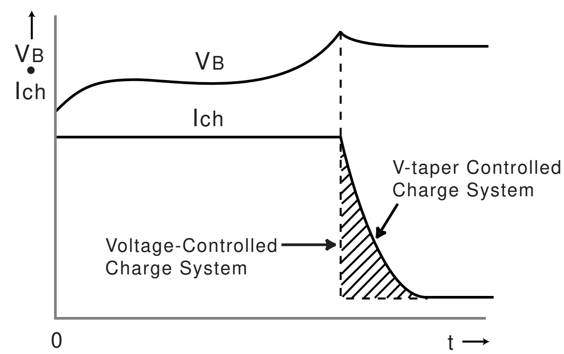


Fig. 12 Charge Characteristics of the V-taper Controlled Charge System

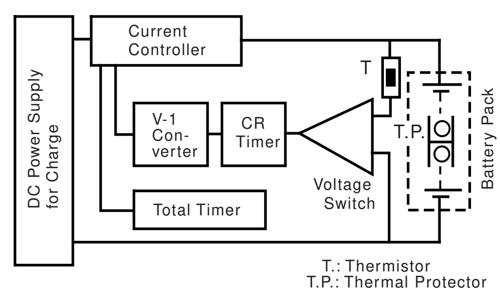


Fig. 13 Circuit Block Diagram of the V-taper Controlled Charge System

(2) Features

- This is the recommended charge control system for Sealed Lead Acid batteries.
- In comparison with the voltage-controlled charge system, this method is capable of increasing the charge level by the amount indicated by the shaded area in Fig. 12. However, just as for the voltage-controlled charge system, the setting of the detection voltage is extremely difficult when charge Ni-Cd batteries.

(3) General Specifications

Because this system is currently used only as a rapid charge method for Sealed Lead Acid batteries, the specifications are not included here.

(4) Precautions

This charge method is basically the same as the voltage-controlled charge system, and it is not appropriate for charge Ni-Cd batteries.

Constant-voltage, Constant-current Controlled Charge system

This is the basic charge system for Sealed Lead Acid batteries, and it is not recommended for charge Ni-Cd batteries.

(1) Mechanism

The charge voltage of Sealed Lead Acid batteries rises sharply at the completion of charge and is subsequently maintained at that level. The constant-voltage, constant-current controlled charge system utilizes these charge voltage characteristics to complete (control) charge using only a constant-voltage power supply with no external control. When the battery voltage is lower than the constant voltage, charge is carried out in the constant-current range, and when the battery voltage reaches the level of the constant-voltage, the charge current is decreased to a trickle current.

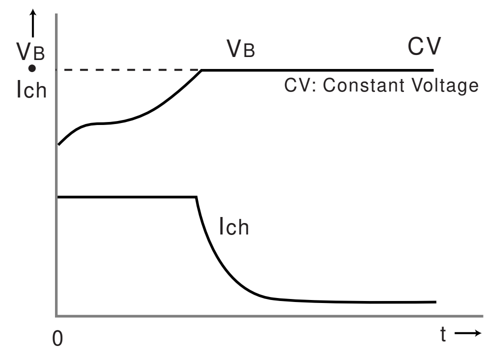


Fig. 14 Charge Characteristics of the Constant-voltage, Constant-current Controlled Charge System

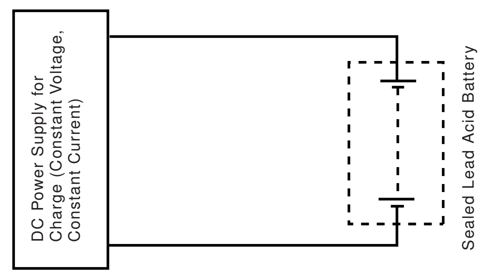


Fig. 15 Circuit Block Diagram of the Constant-voltage, Constant-current Controlled Charge System

(2) Features

Because this method is used only for charge Sealed Lead Acid batteries, the features are not included here.

(3) General Specifications

Because this method is used only for charge Sealed Lead Acid batteries, the specifications are not included here.

(4) Cautions

The charge voltage characteristics of Ni-Cd batteries exhibit a peak at the completion of charge, and subsequently drop. Therefore, if the constant-voltage, constant-current controlled charge system were to be used to charge Ni-Cd batteries, the charge current would be increased again, and thermal runaway would occur. This method is not suitable, and is not recommended for charge Ni-Cd batteries.

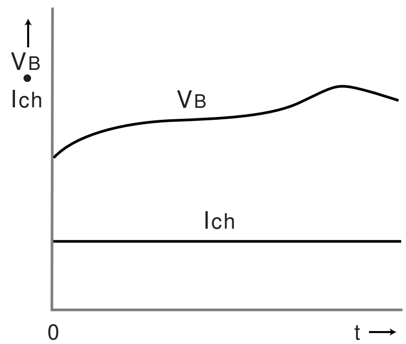
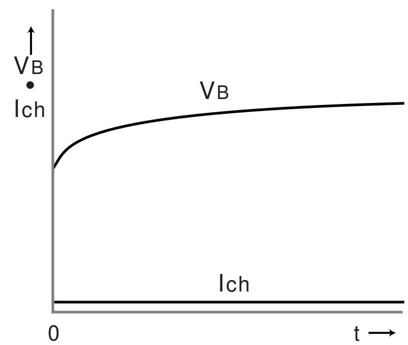
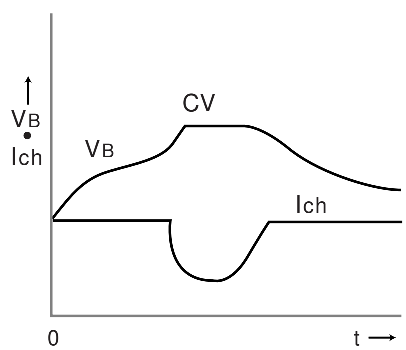
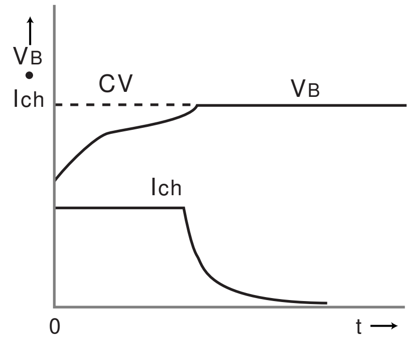
Differences Between the Basic Charge Methods for Ni-Cd and Valve-Regulated Lead Acid Batteries (Previously SLA)

(1) Basic Charge Methods

A comparison of the charge voltage characteristics of Ni-Cd batteries and VRLA batteries shows major differences in the behavior of the charge voltage, such as at the completion of charge. With Ni-Cd batteries, the charge voltage reaches a peak at the completion of charge and subsequently drops, while with VRLA batteries, the charge voltage is maintained at the high level reached at the completion of charge and does not subsequently drop. Due to such differences, the overcharge voltage characteristics also differ greatly between the two types of batteries. Therefore, if the incorrect type of charge system is used, it will be impossible to match the charger to the batteries, thus leading to problems. The following is a summary of the basic charge methods for the two types of batteries.

- For Ni-Cd batteries: Constant-current controlled charge system (Semi-constant-current charge system).
- For VRLA batteries: Constant-voltage, constant-current control led charge system.

(2) General Comparison of the Basic Charge Methods

Batteries	Ni-Cd Batteries	Sealed Lead Acid Batteries
Constant-current Controlled Charge System	(Semi-constant-current Charge System)	Suitable
		
Constant-voltage, Constant-current Controlled Charge System	Not Suitable	Suitable
		
Charge Voltage Characteristics (Summary)	* The charge voltage of Ni-Cd batteries reaches a peak at the completion of charge. Subsequently, however, the battery temperature rises as a result of the overcharge reaction, causing the charge voltage to drop. In addition, in comparison with VRLA batteries, the slope of the voltage at the completion of charge is relatively moderate.	* The charge voltage of VRLA batteries rises sharply at the completion of charge, and is subsequently maintained at a relatively high level.
V_B: Battery Voltage 1ch: Charge Current CV: Constant Voltage		

Typical Examples of Devices and Charge Methods

Recent trends in high-tech devices include smaller sizes, lighter weights, and thinner configurations, resulting in a demand for smaller, lighter, higher-capacity Ni-Cd batteries for use in those devices. One of the most important points in order to take maximum advantage of the characteristics of Ni-Cd batteries is the charge method. The following is a list of some typical examples of devices and of the most commonly used charge methods.

Device	Charge Method	
Portable VCR	Rapid Charge	-ΔV cut off charge system, charge for 1 hour at 1 CmA
	Quick Charge	Timer-control charge system, charge for 8 hours at 0.2 CmA
	Remarks	Charge using a special charger
Notebook PC	Rapid Charge	-ΔV cut off charge system, charge for 1 hour at 1CmA or 2 hours at 0.5CmA.
	Quick Charge	Combination of a timer-control charge system and an temperature cut-off system, charge for 5 hours at 0.3 CmA
	Remarks	* With this type of device, sometimes a special charger is used and sometimes the power supply (charger) is installed right into the device. In the latter case, the power supply capacity is determined by the amount of space available inside the device, and thus the charge time (charge rate) will be determined by that capacity. * If a timer-control charge system is used for this type of device, the timer may be frequently reset (charge re-started). In many cases the system is designed so that the timer is not started by the switching on/off of the power switch on the device, but only by the disconnection of the AC plug.
Cellular Phones and Digital Cordless Phones	Rapid Charge	-ΔV cut off charge system, charge for 1 hour at 1 CmA
	Quick Charge	Timer-control charge system, charge for 8 hours at 0.2 CmA
	Overnight Charge	Semi-constant-current charge system, charge for 15 hours at 0.1 CmA
	Remarks	* Rapid chargers which use a car battery for the charge power supply are commercially available. If the product is destined for a market with a cold climate (for example, northern Europe) and charging at low temperatures is anticipated, a circuit is often added to provide a trickle charge at the beginning when the charge is started at a low temperature. The same type of measure is also used for charging at high temperatures.

Confirming the Charge Specifications

In order to be able to fully display the characteristics of Ni-Cd batteries, it is important to confirm the specifications of the device. Below is a checklist of the points that need to be confirmed regarding the charge specifications.

Charge Specification Checklist

- Applicable batteries __________
- Number of cells used __________
- Charge power supply
  - [ ] AC__________V
  - [ ] DC car battery__________V
  - [ ] Other ___________
- Charge temperature °C to__ °C (Standard charge: 0°C to 45°C); (rapid charge: 10°C to 40°C)
- Charge type
  - [ ] Cycle use
  - [ ] Standby use
  - [ ] Other ____________________________
  - [ ] Semi-constant-current charge (non-controlled)
- Charge current mA
  - [ ] Trickle charge
  - [ ] Timer-control charge
- Timer time hrs.
- Trickle current following timer control mA
- Timer reset method
  - [ ] When charge power supply is input
  - [ ] When battery pack is loaded
- Reset frequency times/day
  - [ ] - ∆V cut-off charge
- Constant-current power supply
  - [ ] Yes
  - [ ] No
- Trickle current following - ∆V control
  - [ ] Yes mA
  - [ ] No
- - ∆V value mV/cell
- Charge mode switch (1) (See Fig. 7.)
  - [ ] Yes ± V/cell
  - [ ] No
- Charge mode switch (2) (See Fig. 7.)
  - [ ] Yes ± V/cell
  - [ ] No
- Initial charge current mA
- Initial delay timer
  - [ ] Yes min.
  - [ ] No
- Total timer
  - [ ] Yes hrs.
  - [ ] No
- Battery temperature detection function
(Detects the battery temperature and switches to trickle charge at beginning of charge.)
  - [ ] Yes, low temperature °C
  - [ ] Yes, high temperature °C
  - [ ] No
  - [ ] Absolute temperature cut-off charge
- Control temperature ± °C
- Trickle current following absolute temperature control
  - [ ] Yes mA
  - [ ] No
- Temperature-detecting elements
  - [ ] Thermistor
  B constant ± %
  R25°C kW± %
- Manufacturer's name __________
  Model No. _________
  - [ ] Thermostat (bimetal type)
- Operating temperature ± °C
  Manufacturer's name __________
  Model No. _________
  - [ ] Other temperature-detecting element
  Element name __________
  Manufacturer's name _________
  Model No. _________
- Retention circuit following completion of charge
  - [ ] Yes
  - [ ] No
- Total timer _________
  - [ ] Yes
  - [ ] No
  - [ ] Other rapid charge control system
- Trickle current mA

Summary of the rapid charge system operation

Two important points for obtaining maximum performance from Ni-Cd batteries

(1) Select a type of battery suitable for the purpose.
(2) Set the charge characteristics correctly. In particular, if the charge conditions are not appropriate, not only will the batteries not display their full performance potential, but the cycle life could be shortened, and in extreme cases, electrolyte leakage could cause damage to the device in which the batteries are used. It is important to consult Panasonic from the initial stages of charger design.

SUMMARY SPECIFICATION TABLES

Cycle Use

Diameter	Size	IEC	Model Number	Type	Nominal Voltage (V)	Discharge Capacity*		Dimension with Tube (mm)		Approx. Weight (g)	Page
						Average (mAh) **	Rated (Min.) (mAh)	Diameter	Height		
N	N	KR12/30	P-18N	N	1.2	190	180	12.0 +0/-0.7	30.0 +0/-1.0	8	40
AAA	AAA	KR11/45	P-25AAA/B	N		280	250	10.5 +0/-0.7	44.5 +0/-1.0	10	41
			P-25AAAR/FT	R						10	42
AA	1/3AA	KR15/18	P-11AA	N		120	110	14.5 +0/-0.7	17.5 +0/-1.0	6.5	43
	(2/3AA)	---	P-30AAR	R		330	300		28.2 +0/-1.0	12	44
	(AA)	---	P-60AAR/FT	R		640	600		48.3 +0/-1.0	21	45
			P-70AARC/FT	R		740	700			22	46
	AA	KR15/51	P-60AA/B	N		640	600		50.0 +0/-1.0	21	47
			P-70AA/B	N		740	700			22	48
			P-100AASJ/B	S		1,080	1,000			23	49
			P-100AASJ/FT	S		1,080	1,000			23	49
	L-AA	---	P-120AAS	S		1,280	1,200		65.0 +0/-1.0	31	50
A	2/3A	KR17/29	P-60AS	S		660	600	17.0 +0/-0.7	28.5 +0/-1.5	18	51
	4/5A	KR17/43	P-110AS	S		1,180	1,100		43.0 +0/-1.5	25	52
			P-120AS	S		1,280	1,200			26	53
			P-150AS	S		1,530	1,500			27	54
	A	KR17/50	P-140AS	S		1,530	1,400		50.0 +0/-1.5	32	55
SC	4/5SC	KR23/34	P-120SCRJ	R		1,350	1,200	23.0 +0/-1.0	34.0 +0/-1.5	38	56
			P-120SCPJ	P		1,350	1,200			39	57
	(SC)	---	P-130SCC	R		1,450	1,300		42.0 +0/-1.5	47	58
			P-140SCC	R		1,550	1,400			48	59
	SC	KR23/43	P-130SCR	R		1,450	1,300		43.0 +0/-1.5	47	60
			P-140SCR	R		1,550	1,400			48	61
			P-180SCR	R		1,950	1,800			49	62
			P-120SCPM	P		1,350	1,200			47	63
			P-170SCRP	P		1,800	1,650			49	64
			P-200SCP	P		2,100	2,000			52	65
	(L-SC)	---	P-230SCS	S		2,490	2,300		50.0 +0/-1.5	57	66
C	C	KR26/50	P-240C	N		2,600	2,400	25.8 +0/-1.0		75	67
			P-280CR	R		3,000	2,800			79	68
D	D	KR33/62	P-440D	N		4,600	4,400	33.0 +0/-1.0	61.0 +0/-1.5	139	69
			P-500DR	R		5,500	5,000			145	70

* 0.2It discharge capacity after charging at 0.1It for 16 hours.
** For reference only.
Battery performance and cycle life are strongly affected by how they are used.
In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as: It(A) = Cn (Ah)/1h.
- [It] is the reference test current in ampres
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
  n = the time base [hours] for which the rated capacity is declared