Proper charging is one of the most important factors to consider when using maintenance-free sealed lead acid batteries. Battery performance and service life will be directly affected by the efficiency of the charger selected. Charging methods are dependent on battery applications like main power application and standby / backup power application.

Main power application (Cycle use):

a) Standard charging (Constant Voltage charging)

b) Rapid charging

Standby / backup power application (Trickle / Float use):

c) Trickle charging

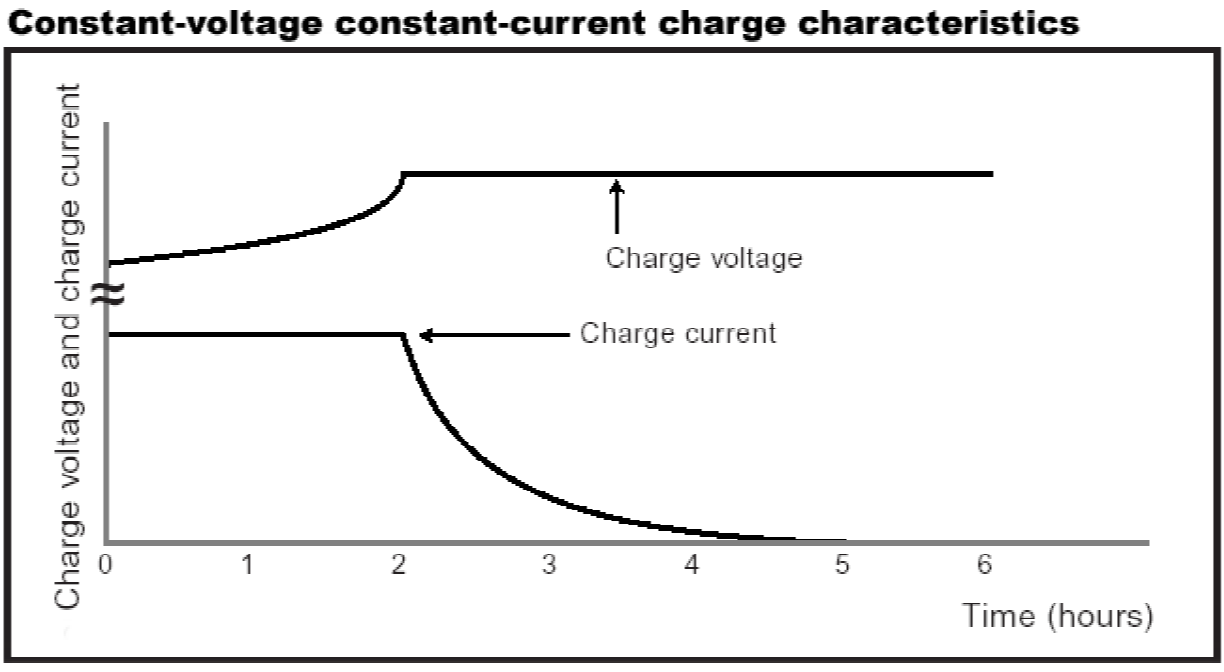
d) Float charging

a) Standard charging (Constant Voltage charging)

For general applications of VRLA battery, the constant voltage charging method is the most suitable and the recommended method of charging for PowerPlus VRLA batteries as it allows the battery to exert full performance.

Constant Voltage Charging Method

This method is to charge the battery by applying a constant voltage between the terminals. When the battery is charged by applying a voltage of 2.45 volts per cell at an ambient temperature of 20°C to 25°C, charging is complete when the charge current continues to be stable for three hours. Valve regulated lead acid batteries can be overcharged if without constant voltage control. When the battery is overcharged, the water in the electrolyte is decomposed by electrolysis to generate more oxygen gas than what can be absorbed by the negative electrode. The electrolyte is changed to oxygen gas and hydrogen gas, and lost from the battery system. As the quantity of electrolyte is reduced, the chemical reactions of charge and discharge become inefficient and hence the battery performance is severely deteriorated. Therefore, exact voltage control and proper charging time in constant voltage charging are essential for securing the expected life of the battery.



This method is to charge the battery by controlling the current at 0.25CA or smaller and controlling the voltage at 2.45 V / per cell at a ambient temperature of 20°C to 25°C. Proper charging time is 6 to 12 hours depending on discharge rate.

b) Rapid charging

When rapidly charging the battery, a large charge current is required in a short time for replenishing the discharged energy. Therefore, some adequate measures such as charging current controlling is required to prevent overcharging when the rapid charging is finished. Basic requirements for rapid charging are as follows:

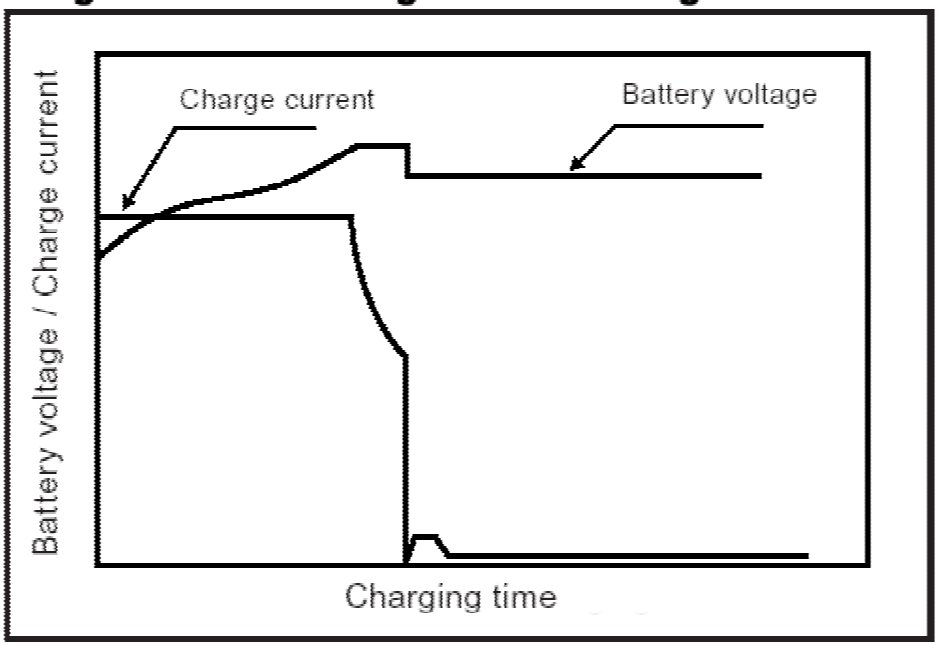
- Sufficient charging should be made in a short time for fully replenishing the discharged amount.
- Charging current should be automatically controlled to avoid overcharging even on prolonged charging.
- The battery should be charged adequately under the ambient temperature range of 0°C to 40°C.
- Reasonable cycle life of charge / discharge should be secured.

Two-stage constant voltage charge control method is the typical methods to control charging so as to satisfy the above requirements.

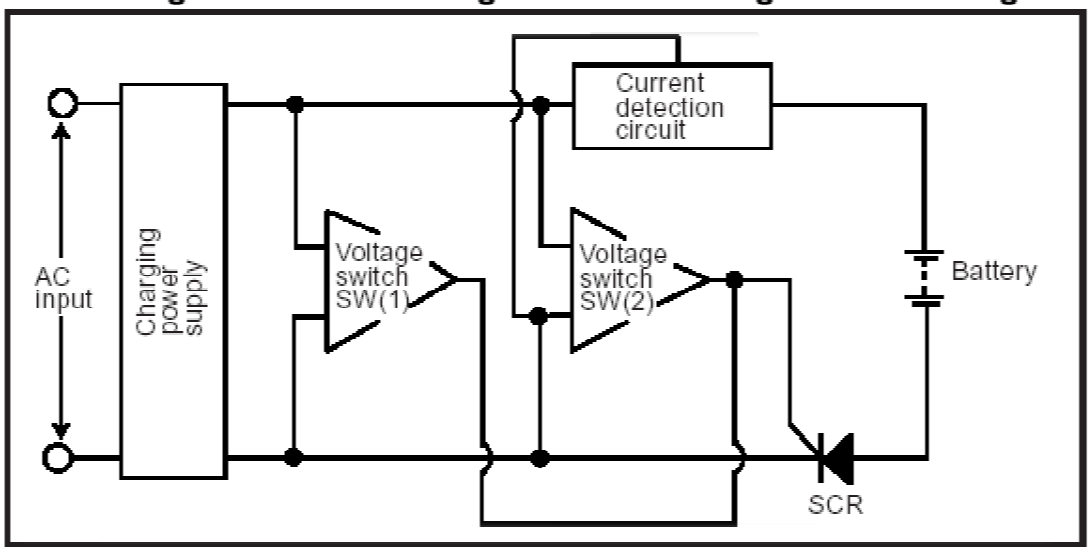
Two-stage constant voltage charge control method

Two-stage constant voltage charge control method uses two constant-voltage devices. At the initial stage, the battery is charged by the first constant voltage device SW(1) of high setup voltage (setup for cycle charge voltage). When the charging current, the value of which is detected by the current-detection circuit, has reduced to the preset value, the device is switched over to the second SW(2) of low setup voltage (setup for trickle charge voltage). This method has the advantage that the battery in trickle use can be charged in a comparatively short time for the next discharge service.

Charging characteristics of the two stage constant voltage control charger



Block Diagram of the two stage constant voltage control charger



Standby / Backup use (Trickle use)

The application load is supplied with AC power in normal state. Standby / Backup use is to maintain the battery system at all times so that it can supply power to the load in case the AC input is disrupted (such as a power failure). There are two methods of charging for this use.

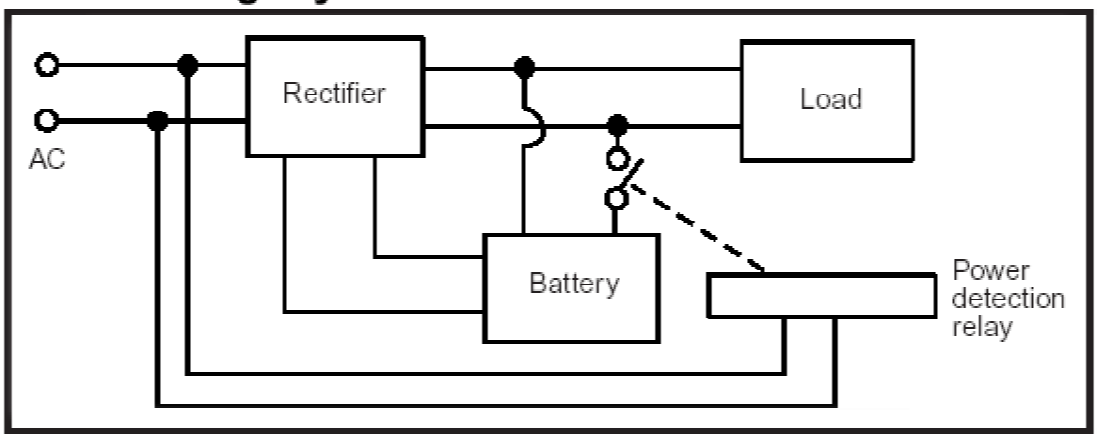
- Trickle charge (Compensating charge)
- Float charge

Trickle charge

In this charge system, the battery is disconnected from the load and being kept charged with a small current only for compensating self-discharge while AC power is running. In case of a power failure, the battery is automatically connected to the load and battery DC power is supplied. This system is applied mainly as a spare power source for emergency equipment. In this use, if rapid recovery of the battery after discharge is required, it is necessary to consider the recovery charge with a comparatively large current then followed by trickle charge, or alternative measures.

While the type and capacity of the battery is determined by the backup time and the load (current consumption) during power failure, some reserve power should be taken into account considering such factors as ambient temperature, charger capability and the depth of discharge etc.

Trickle charge system model



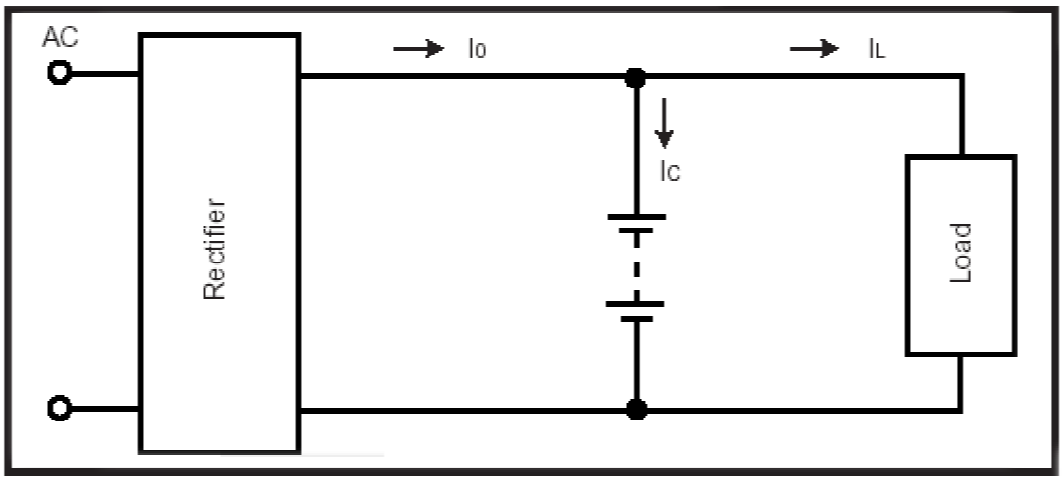
Precautions on charging

1. As the battery continues to be charged over a long period, a small difference in charging voltage may result in a significant difference in the battery life. Therefore, charging voltage should be controlled within a narrow range and with little variation for a long period.
2. As charging characteristics of the battery are dependent on temperature, compensation for temperature variation is required when the battery is used over a broad temperature range, and the system should be designed so that the battery and the charger are kept at the same temperature.

Float charge

Float charge system is the system in which the battery and the load are connected in parallel to the rectifier, which is supplying a constant voltage current.

Float charge system model



In the above-illustrated model, output current of the rectifier is expressed as: $I_O = I_C + I_L$ where I_C is charging current and I_L is load current. Consideration should be given to secure adequate charging because, in fact, load current is not constant but irregular in most cases.

In float charge system, capacity of the constant-voltage power source should be more than sufficient against the load. Usually, the rectifier capacity is set at the sum of the normal load current plus the current needed for battery charging.

Charging Methods and Applications of VRLA Batteries

Charging Method	Normal charging in 6 or more hours; Constant voltage control	Two-stage constant voltage control	Constant current control
Cycle use	Control voltage: 7.25 to 7.45 Volts per 6 Volt battery 14.5 to 14.9 Volts per 12 Volt battery Initial current: 0.25CA or smaller		
Trickle use	Control voltage: 6.8 to 6.9 Volts per 6 Volt battery 13.6 to 13.8 Volts per 12 Volt battery	Initial charging current of approx. 0.15CA, followed by switching voltage to trickle charge	
Float use	Control voltage: 6.8 to 6.9 Volt per 6 Volt battery 13.6 to 13.8 Volts per 12 Volt battery Float charging compensates for load fluctuations.		
***Refreshing charge**	When charging two or more batteries at a time, select only those which have been left under the same condition.		Charging with current of approx. 0.1CA
Applications example	General uses, UPS, Lanterns, Electric tools	Medical equipment, Personal radios	Storage

Note * Refresh charge amount should be 120 to 130% of self-discharge amount.

Precautions on charging

1. (i) in constant voltage charging (cycle use): initial current should be 0.25CA or smaller.
   (ii) in V-taper charge control system: initial current should be 0.8CA or smaller.
   (iii) in constant voltage charging (trickle use): initial current should be 0.15CA or smaller.
2. Relation between standard voltage value in constant voltage charging and temperature is shown as below table.

Temperature		0°C	25°C	40°C
Cycle use	4V	5.1	4.9	4.7
	6V	7.7	7.4	7.1
	8V	10.2	9.8	9.5
	12V	15.4	14.7	14.2
Trickle use	4V	4.7	4.6	4.5
	6V	7.1	6.8	6.7
	8V	9.4	9.1	8.9
	12V	14.1	13.7	13.4

(i) Temperature compensation of charging voltage

Charging voltage should be compensated to the ambient temperature. Main reason for the temperature compensation of charging voltage are to prevent the thermal runaway of the battery when it is used in high temperature condition and to secure sufficient battery charging when it is used in low temperature condition. Prolongation of battery service life by the above described temperature compensation is expected as follows:

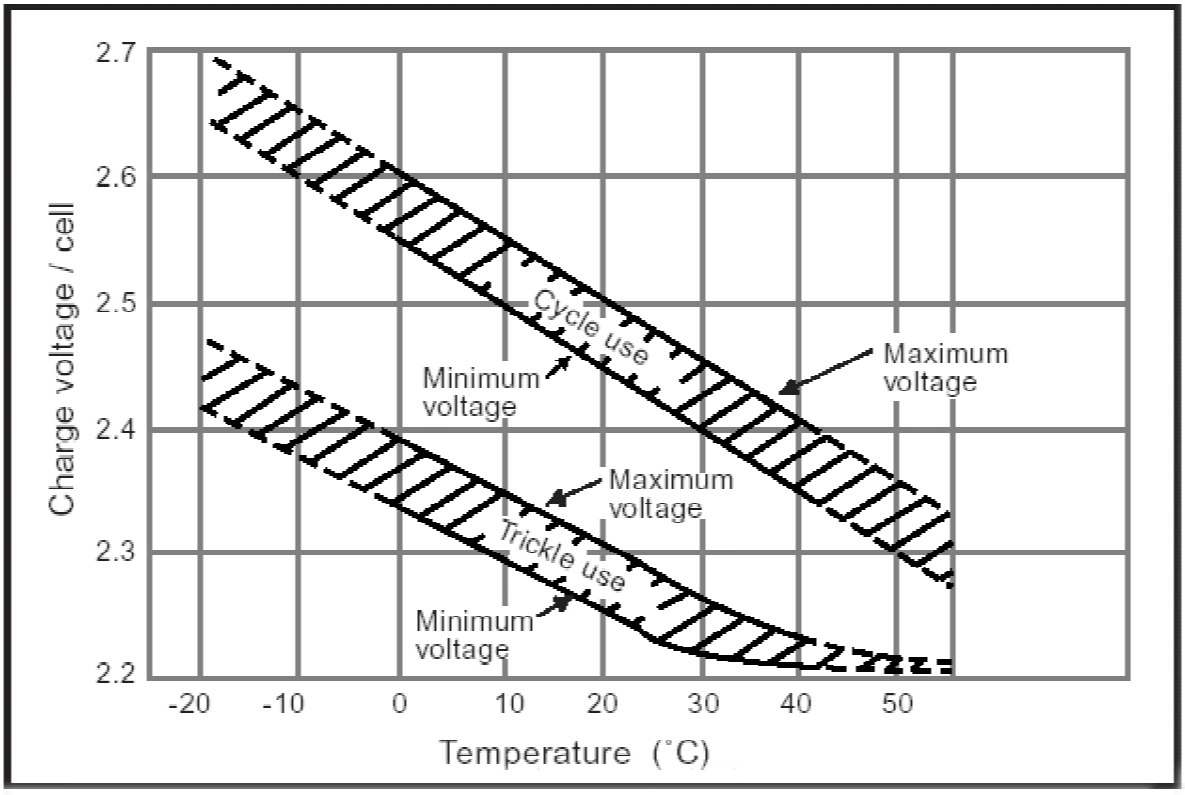
At 30°C: prolonged by approx. 5%

At 35°C: prolonged by approx. 10%

At 40°C: prolonged by approx. 15%

No substantial prolongation of the battery life can be expected by the temperature compensation of charging voltage in below 20°C temperature.

Compensated voltage value



(ii) Charging time

Adequate time required to complete battery charging depends on factors such as depth of discharge, characteristics of the charger and ambient temperature. For cycle use, charging time can be estimated as follows:

(1) when charge current is 0.25CA or greater: $T_{required} = C_{discharge} / I_{initial} + (3 \text{ to } 5)$

(2) when charge current is below 0.25CA: $T_{required} = C_{discharge} / I_{initial} + (6 \text{ to } 10)$

$T_{required}$: charging time required (hour)

$C_{discharge}$: Amount of discharge before this charging (Ah)

$I_{initial}$: initial charge current (Ampere)

Time required for trickle charge ranges from 24 to 48 hours.

(iii) Charging temperature

1) Charge the battery at an ambient temperature ranged from 0°C to 40°C.
2) Optimum temperature range for charging is 5°C to 35°C.
3) Charging at 0°C or below and 40°C or higher is not recommended: at low temperatures the battery may not be charged adequately; at high temperatures, the battery may become deformed.
4) Charging voltage should be compensated to the ambient temperature.

(iv) Never charging in reverse position

Never charging the battery in reverse position. It may cause leakage, heating or bursting of the battery.

(v) Avoid overcharging

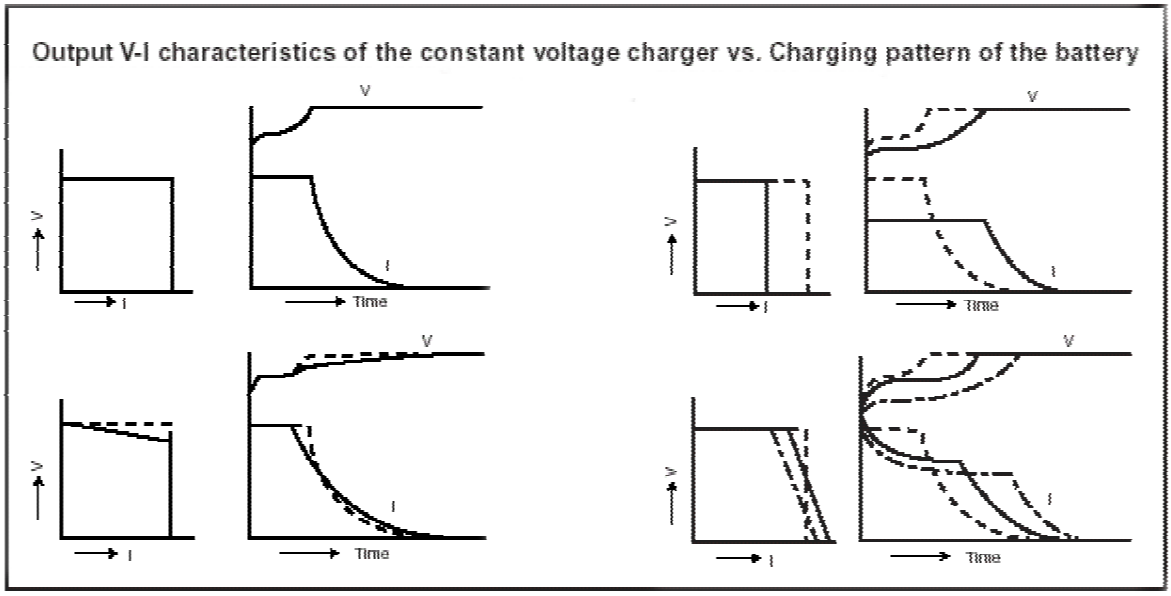
Overcharging is an additional charge after the battery is fully charged. Continued overcharging will shorten battery service life.

(vi) Refreshing charge during storage

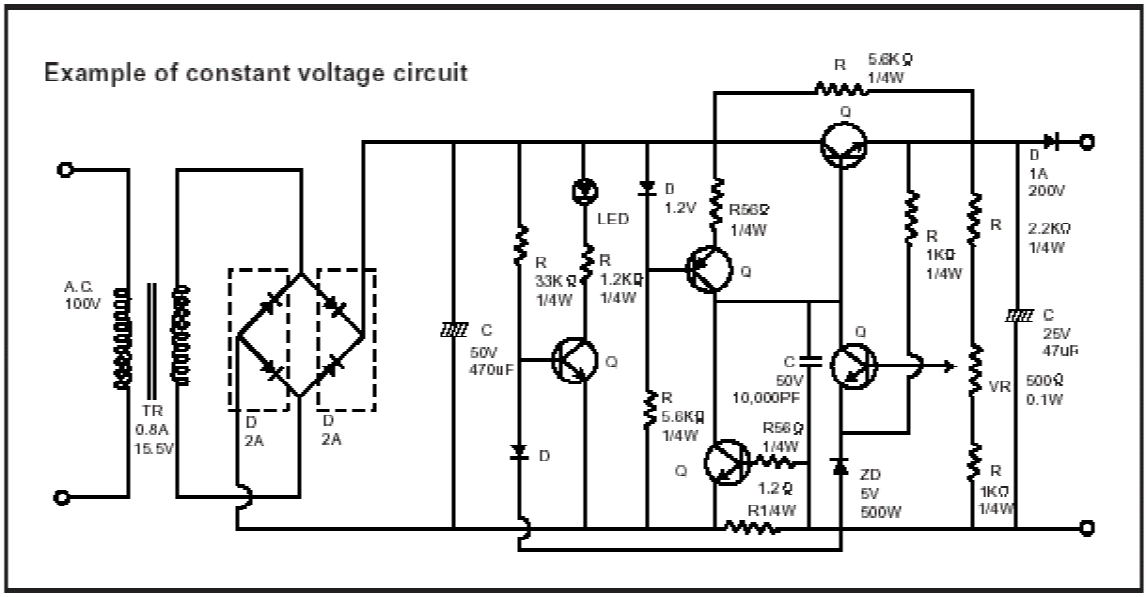
Recharge the battery before use to compensate for capacity loss due to self-discharge during storage.

Characteristics of constant voltage chargers

Even with the same voltage setup, charging time varies with output V-I characteristics.



Constant voltage charger circuitry (Concept diagram)



Precautions

1) When adopting charging methods and charging conditions not described in the specifications, thoroughly check charging / discharging characteristics and life characteristics of the battery in advance. Appropriate charging method and condition selections are essential for battery safe use and for fully utilizing its discharging characteristics.
2) In cycle service, use a charger equipped with a charging timer or a charger in which charging time or charge amount controlled by other means; otherwise it will be difficult to judge the completion of the charging. Use of a charger as described above is recommended to prevent not sufficient charge or overcharge which may cause deterioration of the battery characteristics.
3) Continue charging the battery for the specified time or until the charge completion lamp, if equipped, indicates completion of charging. Interruption of charging may cause a shortening of service life.
4) Do not recharge the fully charged battery repeatedly, as overcharge may accelerate deterioration of the battery.
5) In cycle service, do not continue charging for 24 hours or longer, as it may accelerate deterioration of the battery.
6) In cycle service, avoid charging two or more batteries connected in parallel simultaneously: imbalance of charge / discharge amount among the batteries may shorten the life of batteries.