Battery Charging Techniques - "a science in itself"

Batteries are electrochemical energy storing devices that offer independence of stationary power supplies. Modern electrically driven equipment uses less and less energy, thus prolonging the independence. To take full advantage of the possibilities, the battery charger is of vital importance.

There are several different types of charging techniques and power sources. Power sources commonly used are mains power, generator sets or alternators, but also solar cells and wind power generators are used more and more. The charging technique necessary depends on type of battery, battery usage and power supply. We will focus on mains power and type of usage. Other types of power supply and different types of batteries are mainly special adaptations of the same chargers.

Simple Mains Charger (aka ‘Super Market Charger’)

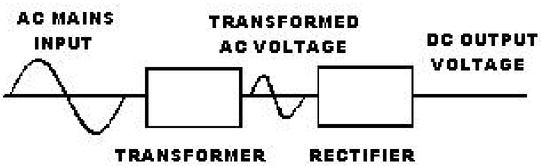
The simple transformer charger is the least complicated and cheapest charger on the market. This type of charger can be purchased in any hardware or auto accessories store. The charging voltage is not regulated and varies, depending on the input voltage and the state of charge of the battery. It means that the charging voltage sometimes is so low that no charging takes place or sometimes so high that severe overcharging may occur. As soon as the AC input voltage for one reason or another is reduced (as found with power generator equipment or rural mains supply), the battery will get an insufficient charge. Deviations in the mains frequency and shape of the AC input current has an adverse effect on the charging result. The conventional charging technique using a transformer and rectifier has many disadvantages. The chargers are usually quite big and heavy and emit large amounts of heat due to their inefficiency (usually around 30-40%). Many of them also have a disturbing humming noise. At low input voltages they may work but at a greatly reduced effect (low input = low output). **Some manufacturers will rate their charger outputs in RMS current so as to make the rated output appear quite large whilst listing in small print the actual *continuous output*. Typical examples are 4A RMS = 2.5A continuous, 8A RMS = 4.5A continuous. BE ALERT! This type of charger must be used under supervision as it has no charge control circuitry.**

Diagram 1.

The simple charger basically consists of a step down transformer (240v to 16v!)and a diode bridge rectifier, which converts the stepped down AC voltage to DC voltage.

Some simple chargers also come with a simple LED voltmeter, which is used to approximate when charging is complete. This type of charger has a maximum output of 15 volts which will destroy a battery!!

If the AC mains voltage drops so does the output resulting in little or no charge. If the voltage increases so does the output usually beyond the maximum allowable voltage prescribed by the battery manufacturer.



Theses chargers are not automatic or intelligent and can damage a battery through overcharging or undercharging. How is a user supposed to gauge when the battery is fully charged?

Recharge Voltages

>14.8v	All batteries are damaged
14.5v	Batteries 100% charged
14.1v-14.4v	Average recharge voltage for most 12v batteries @ 20ºC
13.8v	Minimum recharge voltage for all 12v lead acid batteries @ 20ºC. Also used as a float voltage to offset self discharge.

Automatic Mains Chargers

For those applications where a battery must be charged regularly, this type of charger presents a better choice. The regulation in these chargers prevents overcharging and they can be left without supervision. To charge a battery to 100%, perfect conditions are required. As found with the simple charger above, variations in the AC input voltage as well as deviations in the mains frequency and shape of the AC input current will result in an insufficient charge leading to shortened battery life. This type of charger is intended for regular or continuous use and is recommended when perfect conditions are available.

In transformers, the difference between input and output voltages depends on the number of windings. A change of input voltage automatically changes the output voltage. Many manufacturers of transformer type chargers state in their specifications a range of input voltages. Whether the charger produces 100% of rated effect throughout this range or not, nothing is said. The efficiency of these chargers is 60% maximum due to their usual linear circuits.

Automatic Switch Mode Chargers

This type of charger is designed for continuous use without any supervision. It will charge a battery fast, safely and efficiently. This is the best choice for charging a battery. There isn't any overcharging and no influence on the charging efficiency due to variations in the input power, be it voltage, shape or frequency. The switch mode charger has a very low weight factor, small dimensions and is very quiet (no humming noise). It also has a high efficiency rating (80% or more) and will therefor emit very little heat. This type of charger can be recommended for all types of charging.

When charging a battery, it is most important that the output from the charger is 100% controlled. If the input voltage is reduced by 10% the resulting reduction in output will substantially decrease the charging as found with Simple and Automatic Mains Chargers. The battery will not become more than 50% full. A 20% reduction will result in practically no charging at all with these type of chargers.

Modern switch mode power circuits, used today in every computer, offer the ideal way supplemented with charging logics, to charge batteries quickly, safely and efficiently to 100%. Diagrams 2 and 3 shows the basic switch mode charger and how the voltage is adjusted to give correct output from varying input voltages.

Diagram 2

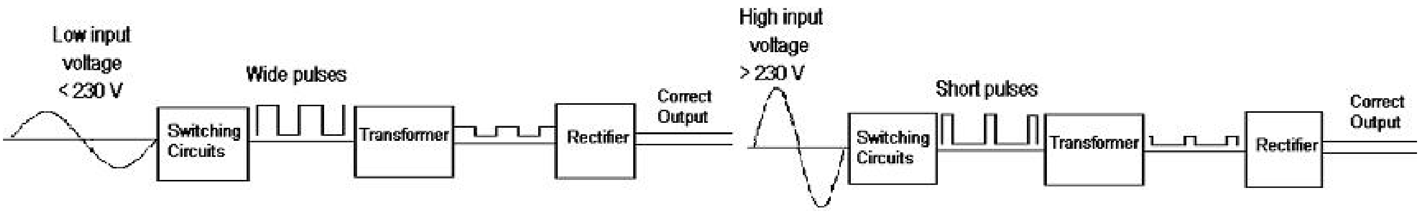
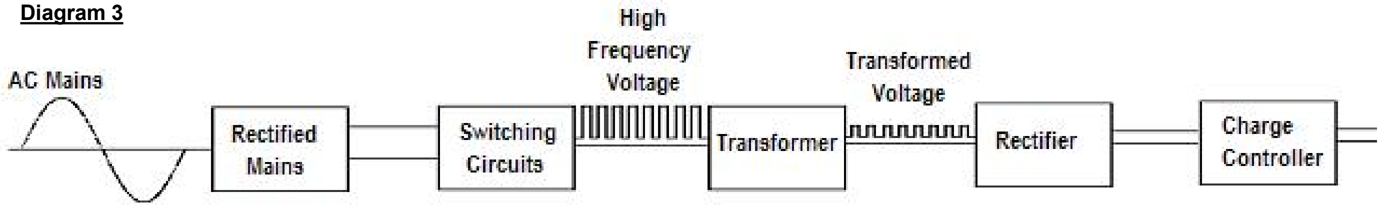


Diagram 3



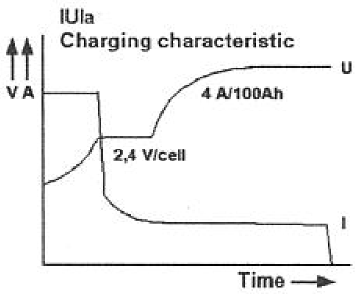
Charging Characteristics

The different charging methods differentiate from other through how the current and voltage are regulated during charging and over charging time. According to DIN 41 772 the current symbols have the following meanings.

Symbols:

I = constant current phase U = constant voltage phase

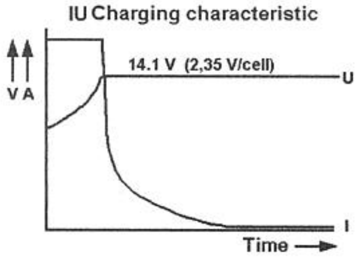
Below are examples of the two most common used types of battery charging philosophy employed in the world today:



IUIa Characteristic

The charging parameters will adjust to the internal resistance of the battery. When the battery is empty the charge cycle starts at a high current (I). Due to increasing voltage (V), the current will decrease accordingly.

When a predetermined set point is reached the charger will shut itself completely off. Note: this type of charger does not have a float or trickle charge available to offset the self discharge characteristics of the battery. If the set point was the gassing voltage of the battery (14.6-15.0 volts), the battery has only attained an apex voltage of around 75%. At higher set points the voltage would continue to increase and eventually damage the battery. Normally the battery will not be totally discharged when the charging cycle starts which means that this type of charger rarely charges with maximum charging current



IU Characteristic

This is the charging characteristic of EPS chargers sold by Tek Trek P/L. The charger will start with maximum charging current and keep this level until a pre-set voltage, normally gassing voltage, has been reached. This voltage is then kept constant by a microprocessor while the current decreases and the charge level of the battery increases until the battery is fully charged. Then the charger will switch to the second constant current level (2.3v/cell). This is the maintenance charging level that will replace self-discharge or consumption from the battery, up to the capacity of the charger.

Small Dimensions But Efficient

All Tek Trek chargers will charge quickly and efficiently using the IU characteristic. When the batteries are fully charged, a Tek Trek charger will keep them that way via its automatic maintenance (float) charging mode. If the power consumption remains below the rated capacity of the charger, the batteries will remain fully charged.

Ripple Current

Tek Trek chargers are also most suitable for immobilised gel electrolyte batteries, lead calcium and flooded cell nickel cadmium batteries, both in terms of charging characteristics and the quality of the DC current. Conventional battery chargers often have a remaining AC ripple in their DC current outputs. Due to the switch mode technique, all Tek Trek battery chargers and power supplies do not have this problem which can cause raised battery and circuit temperatures and premature failure. All Tek Trek battery chargers and power supplies have 100% pure DC output.

Fully Charged - Not Always A Matter Of Course

Even though battery chargers using the IU charging characteristics give a better charging performance than chargers using other characteristics, it does not mean that they will a 100% fully charged battery.

Most IU chargers have a much too short constant charging phase in relation to their rated output and compared to the battery capacity being charged. To achieve a fully charged battery care must be taken to match the rating of the charger to the capacity of the battery and to allow sufficient time in the constant voltage phase.

Many chargers having a timer set for a maximum of 4 hours will show a full battery status sooner. For bigger capacity batteries this is insufficient. These types of chargers are recommended for "smaller capacity" batteries only.

The automatic feature of Tek Trek chargers is a timer, set for 8 hours and can thus be used for both small and larger type batteries. The microprocessor controller in Tek Trek chargers will compute the correct length of time for the constant current phase and thus charge a larger range of batteries correctly.

Deep Discharge

To avoid further damage to batteries that have been deeply discharged, they should be charged with reduced effect until reaching a safe voltage. The microprocessor controller in Tek Trek chargers will, when batteries are discharged below 1.65v/cell, start at a low current that will gradually increase to full effect. This ensures that the minimum damage will result from a deep discharge cycle. All Tek Trek automatic chargers start from 0 volts whereas many other chargers need a voltage of at least 7 volts to start the charge cycle.

Input Voltage

Conventional chargers regardless of how good they are do not work well when the input voltage drops more than 10% below the mains voltage (115VAC in USA/Japan), or when the shape or frequency deviates from standard. This can be improved by various means of design around the transformer but at the expense of efficiency (ie less than 60%). Due to the flexibility of the switch mode technique, Tek Trek chargers will give full power from 90/180V to 265V, still with the same efficiency. They are also insusceptible to deviations in sinusoidal shape or standard frequency. This feature makes Tek Trek chargers eminently suitable for use in third world economies or with power generator sets that often deliver fluctuating current and voltages.

Tek Trek Automatic Microprocessor Controlled Battery Chargers

There are many good reasons for using a Tek Trek battery charger. Designed with switch mode techniques gives Tek Trek chargers technical advantages that translate to economic advantages in terms of lower power consumption and prolonged battery life.

The microprocessor in Tek Trek chargers will consider the voltage and capacity of the battery during charging. It will also control the charging time to achieve the correct level of charging. All Tek Trek chargers will start up at a battery voltage of only 1 volt. Deeply discharged batteries will get a soft start with lower current, to avoid damage to the battery.

When a Tek Trek charger is connected to a battery but not to any mains power, the level of consumption from the battery is approximately the same or lower as the self discharge of the battery. While connected to a mains power source but not to a battery, the power consumption is less than 0.03Amps.

Cos/Pi (The Efficiency Factor)

The Cos/Pi Factor relates to the power consumption from the mains power supply. Their cos/pi rating is often around 0.6 and all Tek Trek chargers and power supplies in parallel.

Power consumption from AC mains depends on the cos/pi factor. Conventional linear chargers often have a cos/pi factor of 0.6 while Tek Trek chargers and power supplies have a cos/pi factor of 1.17. Below shows the difference:

450 watt Average Conventional Charger:

$\frac{450W}{0.6} = 750VA$ (Volt/Ampere)

At 240VAC the resulting current is: $\frac{750VA}{240VAC} = 3.125A$

450 watt Tek Trek Charger:

$\frac{450W}{1.17} = 384VA$ (Volt/Ampere)

At 240VAC the resulting current is: $\frac{384VA}{240VAC} = 1.6A$

Why waste precious money with inefficient technology?

As you can see the conventional charging draws 3.12A from the mains while the Tek Trek charger consumes only 1.6A from the same mains power. This is one of the main features of Tek Trek chargers and power supplies over and above all other types available in the world market today.

Although Tek Trek chargers rarely get warm, high ambient temperatures can cause the internal temperature in the charger to raise above +60ºC. When this happens the built-in fan (Models EPS1225 upwards and EPS2425 upwards) will start. If the temperature in anyway raises above 70ºC, charging current will be reduced to protect the charger and battery/s from overheating and resulting in damage.

The microprocessor controlled switch mode technique has made it possible to give Tek Trek chargers a functional and pleasing design with no humming from the transformer, easy to change microprocessor for adaptation of charging characteristic to a different type of battery and adaptations of housing or other features for special purposes are also possible.

Tek Trek chargers are characterised by low weight and compact dimensions. They start at 200g in weight (PW108) and the larger models are around the size of a shoebox (usually considerably smaller) which makes them ideal for tight places.

Worldwide Compliances

All Tek Trek battery chargers have been tested by SGS for compliance with Australian and European Standards and RFI norms.

Tek Trek chargers are compliant with the following standards and battery manufacturers:

AS3193
AS3696-14

All Tek Trek Battery Chargers are approved by Dryfit, Century, Yuasa, Panasonic, BP Solar, GelTech, Deka, CSB, GNB Technologies and are used across Australia and worldwide

Accepted and used by

Battery Charging Voltages

Volts Check - Wet Cell Lead Acid Batteries:	**12 Volt system**	**24 V system**
Battery(s) overcharged and damaged.	over 15.0	over 30.0
Battery(s) near full *while charging* (depends on amps and temp)	14.4-15.0	28.8-30.0
Battery near empty *while charging* (depends on amps and temp)	12.3-13.2	24.6-26.4
Battery full with light loads (depends on amps and temp)	12.4-12.8	24.8-25.6
Battery full with heavy loads (depends on amps and temp)	11.5-12.5	23.0-25.0
Battery standing (0 amps input for 12 hours minimum) 100% (full)	12.6-12.7	25.2-25.4
Battery @ 80% charged	12.5	25.0
Battery @ 60% charged	12.2	24.4
Battery @ 40% charged	11.9	23.8
Battery @ 20% charged	11.6	23.2
Battery @ 0% (empty)	11.4	22.8
Battery nearly empty while discharging (depends on amps and temp)	10.5-11.5	21.0-23.0

Table Notes: When a range of voltages is shown in this table, the voltage will be *higher* when more current goes in the battery (charging), and *lower* as more current leaves the battery (discharging). In addition, the temperature affects the voltage as follows: while *charging*, a lower temperature will *increase* the voltage while *discharging*, a higher temperature will *increase* the voltage. There is little temperature effect while the battery is standing being neither charged or discharged.

As can be seen, one important factor influencing the "volts" reading is the "state of charge" of the batteries. ("State-of-charge" will be defined again later, but it means "how full" the batteries are.) Very generally, the battery voltage gradually goes up as the batteries acquire more energy through being charged, and goes down as energy is removed. Often simple "battery full/empty gauges" which are intended to show how full the battery is use only this volts measurement. Variations on this theme are simple voltmeters that control green/yellow/red indicator lamps, often conditioned by a time delay that give a rough indication of "state of charge". The difficulty of using volts to accurately measure state of charge is that the voltage reading is also affected by *how many* amps are being used to charge and discharge. If the batteries have not been either charged or discharged for awhile (several hours) the "volts" reading can be used to get a good idea of "state of charge". However if the battery is being discharged by a load, the "volts" reading will be pulled down depending on how many amps are being discharged. If you start charging them again, the voltage will immediately be pushed up by the charger, again, depending on how many amps are charging.

However, there are two extreme situations where the "volts" reading is particularly useful to tell the battery state of charge: one is while the batteries are *nearly fully charged* while they are being charged. In this case the battery voltage will start to climb more rapidly, and show a value (for a 12 Volt system) of 14.2 volts or higher. (Double this for 24 V systems.) At the other extreme, while discharging, the voltage reading can be relied upon to show that the batteries are nearly depleted of energy, when the reading goes below 11.2 volts (for 12 volt systems--double for 24 volts), and will start to decline more rapidly from there. But as mentioned, when the battery is in intermediate states of charge the voltage curve is "flatter", meaning that the voltage doesn't change as much, so it doesn't work well to gauge the "state of charge".

Table 1 (above) shows the normal range of "volts" for various conditions of battery "state-of-charge", charging or discharging current, and temperature.

An important use of the "volts" reading on a voltmeter is to check that the charging system is working properly. The charging system (which includes solar system "charge controllers") should charge the battery volts up to a certain point, then stop charging or the batteries can be damaged by excessive charging. Similarly, if the voltage does not rise high enough the batteries can be chronically under charged, which will result in "sulphation" and thereby shorten battery life.

Battery Charging Rules

Battery safety > Batteries can be dangerous!

- ***Batteries should never be inaccessible to children. If a metal tool or other conductor shorts across battery terminals it can instantly get very hot and cause a fire or burns.***
- ***Remove metal finger rings while working with batteries, which if they short across battery terminals will cause severe burns. Although rare, rapid discharging of batteries can cause them to explode from generated hydrogen and oxygen gas inside the batteries causing cell caps to pop off and spray acid everywhere.***
- ***When adding distilled water acid could accidentally splash and hit your eyes and hands. Use safety goggles and rubber gloves to protect eyes and hands from this possibility. Purchase a pair of goggles gloves and store them in the vicinity of the batteries so they are handy to use when working around them.***

Lead-acid Battery Rule 1: Try to keep them above 50% state of charge. The general idea is to keep your batteries toward the top of their charge rather than toward the bottom. And if you need to use a recharging source to do this, don't wait until they are all the way to the bottom before turning on the recharger. This rule should encourage you *not* to always wait until the inverter; refrigerator or any other appliance cuts off your power because the system voltage is too low and then charge.

Lead-acid Battery Rule 2: If they do become discharged, recharge as soon as possible. If you do slip below 50% state of charge it isn't going to hurt very much if you get them up to full charge again soon. If they become completely discharged, don't allow them to remain in this state for long--certainly not over 24 hours.
When battery voltage goes below 11.0-11.2 (12 volt systems) or (22.0-22.4 in 24 volt systems) volts the batteries are becoming more discharged than they normally should. The battery capacity may be getting lower than expected due to age or past mistreatment--or they simply may be colder than normal. The "volts" reading is the authoritative indicator that the battery is at or near discharge --for example if the battery system has lost capacity because they are old, or have suffered abuse--or perhaps because they are colder than normal resulting in temporary lower capacity (until rewarmed again). If you discover that the voltage has become excessively low you may want to recalibrate the battery charging system –refer this to Tek Trek.

Lead-acid Battery Rule 3: Fully charge every week or so. Every week (or more often) you should charge the batteries to full charge to offset sulphation. Sulphation of the cells is the death of all lead acid and calcium batteries.

Lead-acid Battery Rule 4: If you have "flooded" lead acid batteries, equalise every 1-2 months "Equalisation" is a term often given to describe the process of occasionally over charging the batteries. "Over charging" is not necessarily synonymous with "abuse"--it just means to put in more energy than the batteries can hold.
One purpose of "equalisation"--from which the name is derived--is to cause all the individual series cells in the battery to become equally charged. However it serves other functions as well. A second function is to do a very complete charge of the battery. When the battery is charged enough for an EPS charger to sense that the batteries are "charged", the battery usually is not yet 100% charged, although it is generally over 85% charged. If some of the battery reaction products remain in their uncharged state too long they undergo changes that make it very difficult to reconvert them back to their "charged" state, thus making the battery progressively more difficult to fully charge. This is referred to as "sulphation" of the battery, which causes eventual loss of capacity. Another purpose of equalisation is to mix up the electrolyte in the battery, which happens because of the gas bubbles that are produced when overcharging.

Of course, just like overflowing a gas tank, equalisation does waste a little energy, but if you don't occasionally equalise, especially if your batteries are often not fully charged, the batteries can gradually lose capacity.

Some charging systems have an automatic equalise function--others have a manual switch. Follow the procedure recommended by your installer, dealer or battery manufacturer. In some cases chargers do equalisation automatically (this is an automatic feature of all EPS battery chargers), and no operator attention is required. In other cases it involves changing a switch position on the controller to "equalise" for a specified amount of time, or for a recommended number of amp-hours overcharge. More frequently, however, rather than keeping track of the number of amp-hours overcharge, a manufacturer may recommend that the voltage be raised to a fairly high voltage for a set period of time, for example the Trojan battery company recommends 15.5V for 4 hours for a 12V battery system, performed every month or two, with charging at a rate of C/20 or less, where C=capacity of the battery system, in amp-hours. After equalising is usually recommended as the best time to check water levels and add additional amounts of distilled water if necessary. Equalisation generally causes the electrolyte level to rise slightly--so adding at this time minimises the danger of overfilling.

Other miscellaneous battery maintenance items: Periodically check and maintain water level of "wet cell" batteries. Every 2-3 months check the battery water levels. They should not be allowed to fall below the top level of the plates--and should be filled up to the marker--often the bottom of a cylindrical hole covered by the battery cap. Add pure distilled water only--and as mentioned, the best time is just after equalising the batteries.

Keep batteries at correct temperature range. Ideal temperature is 15-25^{o} C. At higher temperatures batteries suffer reduced life. At lower temperatures they have reduced capacity, however even at 0^{o} C they have about 70% capacity, although they don't absorb charging current as readily so it takes longer to charge them fully. If batteries sit below 5^{o} C they can freeze if in a low state of charge, which will destroy the battery. If they are kept reasonably well charged (75% or greater) however, they won't freeze even at minus 10^{o} C or more.

Occasionally check connections. Battery connections can sometimes develop excessive resistance. This will cause apparent loss of capacity, and possibly improper charging of some batteries in a parallel group, which can cause battery damage. Battery tops, being horizontal surfaces, sometimes collect quite a bit of dirt. Occasionally clean these off to reduce possibly of stray current leakage.

If you have questions about battery charging, battery installation, dual battery isolation please free to call

Tek Trek
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With over 40 years of auxiliary power experience and 30 years as a lecturer in battery charging techniques and solar power systems, we are sure that a suitable solution can be found <u>anywhere</u>, <u>any time</u> no matter how big or how small your application is!