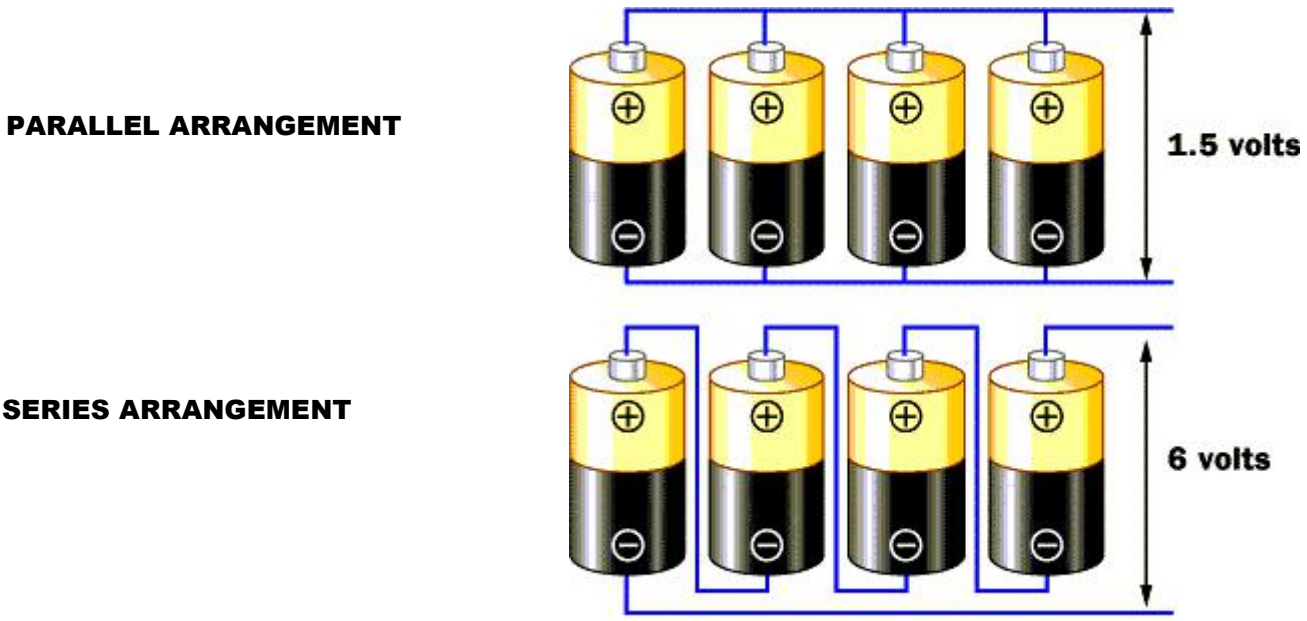
How Battery Packs Work

Battery Arrangements

In almost any device that uses batteries, you do not use just one cell at a time. You normally group them together serially to form higher voltages, or in parallel to form higher currents.

- In a **serial arrangement**, the voltages add up.
- In a **parallel arrangement**, the currents add up.

The following diagram shows these two arrangements:



The upper arrangement is called a *parallel* arrangement. If you assume that each cell produces 1.5 volts, then four batteries in parallel will also produce 1.5 volts, but the current supplied will be four times that of a single cell. The lower arrangement is called a *serial* arrangement. The four voltages add together to produce 6 volts but the current will only be that of one cell.

Normally, when you buy a pack of batteries, the package will tell you the voltage and current rating for the battery. For example, my digital camera uses four nickel-metal hydride batteries that are rated at 1.2 volts and 650 milliamp-hours for each cell. The milliamp-hour rating means that the cell can produce 650 milliamps of current for one hour.

In general, you can scale milliamp-hours **linearly** -- this battery could produce 325 milliamps for two hours or 1,300 milliamps for half an hour. It is not completely linear -- all batteries have a maximum current they can produce, and many battery chemistries have longer or shorter than the expected life at very low currents -- but it is generally linear over a normal range. Using the **amp-hour rating**, you can estimate how long the battery will last under a given load.

If you arrange four of these batteries in a serial arrangement, you get 4.8 volts (1.2 x 4) at 650 milliamp-hours. If you arrange them in parallel, you get 1.2 volts at 2,600 (650 x 4) milliamp-hours otherwise known as 4.8VDC @ 2.6Ah.

Have you ever looked inside a normal 9-volt battery?

It contains six, very small batteries producing 1.5 volts each in a **serial arrangement**.

Different types of batteries are frequently used & relied on in video field production. It's important to understand the different types if you are to get maximum usefulness & long life out of them. Here are three common types (lead acid, Nicad & NiMH) & their characteristics. This tutorial is a work in progress & will be added to as time permits.

Glass Mat & Gel Cell Sealed Lead Acid Batteries (VRLA):

Overview: Sealed glass mat or gelled (gel cell) lead acid battery types are frequently used in video equipment because liquid (wet / flooded) cell lead acid batteries (like car batteries) can leak acid as they are vented (not sealed). Glass mat & gel cells are inexpensive compared to nicad batteries BUT they do not have a "memory" problem like nicads. Unfortunately, unlike nicads, lead acid batteries are easily damaged if they are left in a deep discharge condition, or if they are overcharged, so it is important to charge them up immediately after use & to use a quality charger designed for lead acid batteries. 12 Volt glass mat & gel cell batteries are made up of six cells inside a battery, each of which is nominally about 2.15 Volts for a total of about 12.9 Volts charged, with no electrical load. Glass mat batteries use a very thick paste (thick like candle wax or toothpaste) of sulphuric acid electrolyte between the positive plates (lead dioxide) & negative plates (sponge lead) of the battery, with a porous insulator between plates so they don't short out. Gel cell batteries are similar except the electrolyte is like a jelly. The plates in a glass mat or gel cell are relatively thin compared to wet cell lead acid batteries, so glass mat or gel cells discharge/charge a bit faster than wet cells. Glass mat or gel cells have no fluid movement within the battery like wet lead acid and are therefore maintenance free because they cannot be topped up with electrolyte. For this reason, it is very important to have a high quality charger that doesn't boil off the electrolyte (called gassing), as this would dry out the electrolyte and cause the battery to fail. After several years of useful life, all rechargeable batteries should not be disposed of in regular garbage which goes in a landfill site, but instead you should contact your municipality for the location of a hazardous waste site or seek a metal recycler.

Charge/discharge rates: Glass mat, gel cell & wet lead acid batteries have a high internal impedance (resistance), so they will stay in a charged condition longer than nicad batteries before they self discharge, though glass mat & gell-cell lead acid batteries don't self discharge as quickly as wet lead acid batteries. Unfortunately this high internal impedance also means that lead acid batteries can't put out as much current (Amperage) over a short period of time as a similarly sized nicad battery, plus glass mat or gel cells can take longer to charge than nicad batteries. A rough rule of thumb is that a wet lead acid battery can only accept a charge of no more than 25% of it's Amp/hour rating up to about the 80% charge level, called the "bulk charge", then charge more slowly from 80-100%. This is called the "equalization" or "absorption" or "acceptance" stage. A glass mat or gel cell lead acid battery accepts a higher discharge/charge rate than liquid lead acid because of it's thin close together plates and can be charged at an average of up to 40% or more of it's Amp/hour (Ah) rating up to the 80% charge level, then charge more slowly from 80-100% (i.e. taking a minimum of 2.5 - 3.12 hours to charge a typical fully discharged glass mat or gel cell battery using an intelligent charger). The charge pattern isn't linear and a lead acid battery will accept more of a charge when it is nearly empty (sometimes at a 60 - 70% rate). The charger must gradually taper off that current charge or pulse charge as the battery starts to fill up (over 80% full) as well as limit the voltage or it will overcharge causing the battery to get warm and gas, which damages the battery. A slightly warm battery during heavy discharge or charging is ok, but a really hot glass mat or gel cell battery indicates that damage is being done to the battery.

Quality charger & regulator: A lead acid battery requires a charger with a slightly different voltage charge level and different end of charge methods than a nicad charger. Because Glass mat or gel cell batteries are so easily damaged by overcharging compared to nicad batteries, the charger must intelligently limit the voltage level and taper or pulse the current (Amperage) level when topping off of the charge. Voltage levels on a lead acid battery during charge should typically be regulated to be between 13.6 & 13.8 Volts for the float level, sometimes going as high as 14.2 Volts (maximum 14.4 Volts at 25degC max.) for pulsing or end of bulk charge stage. Once a gel cell is almost charged, the "float" level can drop to 13.2 - 13.8 volts and can be trickle charged or pulse charged with very little current for several hours or days using a quality intelligent charger, without damage. Using a proper intelligent charger, glass mat or gel cell batteries do not give off a corrosive vapour (no explosive gases). Very few 12 volt **automatic** car battery chargers in the 10-12 Amp size do a fine job of charging glass mat or gell-cel lead acid batteries in the 6-14 Amp/hour size. Most do not (they overheat & destroy the battery). Cheap car battery chargers which claim "automatic shut off when battery is fully charged" are always poorly designed and built to a price resulting in overcharging and destruction of the battery under charge.

Regardless of the maximum Amp capacity of the charger (i.e. 6, 10, 12 or 15 Amps), **try to choose an automatic charger that will automatically taper down the current (Amperage) right to zero**, so that it will never feed more current (Amps) or volts than the battery can take. An example of a charger that usually does this quite well is the EPS 1208 which is an 8 Amp fully automatic battery charger for automotive, marine and deep cycle batteries. **Deep**

Discharge: As a general rule of thumb, the deeper you discharge a lead acid battery and the longer you leave it in that discharged condition, the more it will shorten the useful life cycles of the battery. Often it is a good idea not to discharge a deep cycle battery beyond 80% of its capacity and car batteries beyond 50% charge level. If you do deep discharge a deep cycle battery beyond 80% and a car battery beyond 50%, it is all the more important to get them charged up immediately, because sulphation can start to occur when a lead acid battery is left in a discharged condition (especially liquid lead acid). This will dramatically reduce the useful life of the battery and void any warranties. It is not uncommon to be able to get 4-7 years of life out of a lead acid battery if it is properly taken care of and depending on the number and depth of the discharge/charge cycles. Liquid lead acid batteries are more susceptible to sulphation than glass mat or gel cell lead acid batteries and for this reason, glass mat or gel cells are more suited for deep discharging, which is common in video, marine, golf cart & handicap applications.

Battery Capacities: Liquid lead acid car batteries are rated in "cold cranking Amps" (which is the number of Amps that can be delivered at 0 degrees F or -17.8 degrees C, to crank an engine for 30 seconds without falling below 7.2 Volts), and rated in "reserve capacity" (which is the number of minutes the battery can deliver 25 Amps at no less than 10.5 Volts at 80 degrees F or 26.7 degrees C). Unfortunately those ratings are meaningless for some other applications such as for video equipment & marine, so glass mat or gel cell batteries are also rated in "**Amp/hours**", which is the number of Amps times hours at nominal 12 volts at 80 degrees F (26.7 degrees C) that the battery can continuously deliver **measured over a 20 hour period** and going no lower than 10.5 Volts. For example, a 20 Amp/hour (20Ah @ C_{20} gel cell battery should be able to deliver 1 Amp at 12 volts (12 Watts) continuously for 20 hours before it is completely discharged. The rating is over 20 hours because glass mat & gel cells have a high internal resistance. The quicker you discharge the lead acid battery, the less total Ah you will get out of it. For example if you discharged this 20 Ah battery at 2 Amps (24 Watts) you would only get 10 Ah (50% of rated capacity). For this reason, with video devices & lights it is generally a good idea to have oversized glass mat or gel cell batteries, than if you were powering the same devices with a nicad battery. A new 12 Ah 12 volt gel cell battery belt, can power a 100 Watt camera light for up to 86 minutes of continuous use before it is fully discharged and the light gets too dim (changing in colour temperature too).