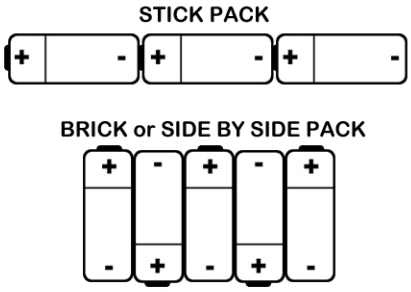
Building RC Battery Packs

One of the main reasons for building (or rebuilding) battery packs, other than the cost savings, is the ability to improve the connections between the cells so the current will flow more easily from one cell to the next with the least amount of resistance. Resistance causes the cells to overwork themselves and heat up. Heat is bad for battery life and performance. The hotter the pack is, the less runtime, current, and life it will give and have. And the hotter your battery runs, the more resistance there will be.

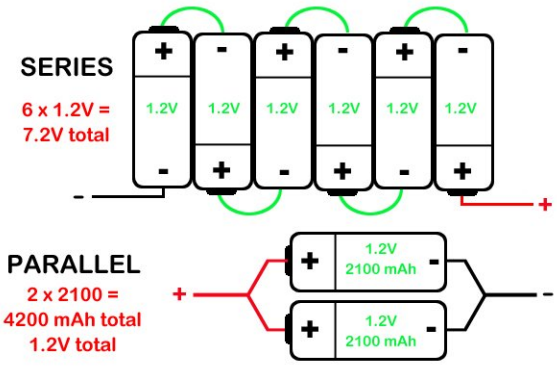
Battery Pack Styles

A common misconception about battery packs is that they are one very large battery when they are actually made up of a number of individual batteries, called cells, that are connected together to work as a single pack. There two basic types of battery packs. Stick packs, or shot-gun, stack the batteries positive to negative ends like batteries in a flashlight. Brick, or side-by-side packs have cells laid next to each other forming a cube or "brick". Which style you use depends on the space available and the voltage you need for your particular model. This information is generally found in the "Items Needed to Complete" section.



Cell Connection Basics

There are two ways that the cells can be connected together. "In Series" is where the positive terminal of one cell is wired to the negative terminal of another cell. With this method, the total voltage of the pack is the sum of the individual cell voltages. For example, a 6-cell NiCd or NiMH pack is made up of cells rated at a nominal 1.2 volts each. When wired in series the total nominal voltage of the pack is the number of cells in the pack (6) multiplied by the voltage of each cell (1.2V in this case) to get the total pack nominal voltage (7.2 volts for this example). This is the most common cell connection method found in the RC hobby.



The second is called "Parallel" where you connect the positive terminal of one cell to the positive terminal of another, and negative terminal of one cell to the negative of another. Wiring cells in Parallel increases the total capacity of the pack *but the nominal voltage remains that of a single cell*. To figure out the actual end result capacity add the mAh rating (milli-amp hour) of the cells. If you put 2 cells in parallel that are each 2100mAh (commonly referred to as "2P"), multiply 2100 by 2 for a total capacity of 4200mAh.

The number of cells you'll need and the configuration of them in your battery pack will depend on what you are powering, how much power you need, the amount of space you have to hold that battery pack, and the weight distribution in your vehicle. In some cases your chassis space for a battery pack is not adaptable, so be aware of those constraints before you start. Check your owner's manual for your vehicle's specifications. It can also be very helpful to draw out the cell configuration and double check your connections and voltage requirement before you begin assembly.

This article assumes that you have a basic knowledge of electronics. If you don't, consult a local hobby shop for help before attempting this.

What You'll Need

- Your required number of 1.2V cells. Check the voltage (off load). Anything less than 1.1-1.2V will indicate a sub-standard cell due to overlong or inappropriate storage.
- Something to connect the cells together with. Options include: Battery bars; large gauge (12 - 18) multi-strand, hi-flex, insulated wire; soldering wick, copper braid, or copper strips.
- High quality 12 gauge multi-strand, hi-flex, insulated wire with a high strand count for the pack leads.
- High quality, thin wire, rosin core, 60/40 solder. This is the type intended for electronics use and desired for quick and accurate work and avoiding battery damage. The rosin is a flux that helps join metals when soldering. You do not want to use solid core, wide diameter solders like that used for plumbing and never use acid core solder for this work.
- 100 Watt Soldering iron with a wide (minimum ¼" or larger) chisel style tip, like Inland's TempTrol 100™ and InstaHeat™ soldering irons at right.

WHEN CHOOSING A SOLDERING IRON

The two most important factors affecting soldering iron performance are wattage and tip size. Wattage is a figure that indicates how much electrical power the soldering iron is using to generate heat. A higher wattage number indicates a better ability for the iron to reach operating temperature. Given two irons that are identical except for their wattage, the higher wattage one will reach a given temperature faster and maintain it better.

The tip size of a soldering iron affects the iron's ability to maintain the tip (an thus your soldering) temperature. A large, heavy tip holds more heat so when you touch it to what you're soldering, the tip temperature doesn't drop as much. However, a tip that is too large may not be heated adequately if the soldering iron doesn't have enough power. So a combination of a good wattage rating as well as a matching tip is what you should look for.

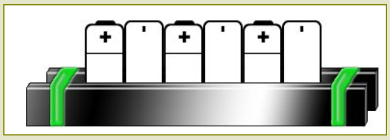
Inland's TempTrol 100™ heats to over 1000°F, comes with a 3/8" tip and has built in temperature control in the handle. The InstaHeat™ heats to 850°F, comes with a 1/4" tip, and has a ceramic core for fast and efficient heating.

- Fast drying adhesive for attaching your cells together. Commonly used products include Shoo Goo, Goop, Carpenters Goop, hot glue or nylon strapping tape.
- Low resistance power connectors if you don't already have them for both the male ESC and female battery connections. It is also possible to hardwire the pack to the ESC and eliminate the need for a connector.
- Shrink wrap for your completed pack and maybe for each of your cells, plus a heat gun or hair dryer to shrink it. You may also want some power lead sized shrink wrap tubing for the connection ends.
- Hand tools: Pair of needle nose pliers, tweezers, hobby knife, wire cutter, and wire stripper.
- Fine grit sand paper or emery cloth. You can also use a moto-type tool with a fiberglass bit or sanding drum or a hand held file.
- Wet sponge for cleaning your iron tip and flux residue.
- Multi Meter to test voltage and polarity.
- Safety Glasses

Other items you may find useful are:

- Assembly Jig: These help keep the cells aligned and held side-by-side during assembly. You can purchase jigs or make your own.
- Soldering "Helping Hands": A device that can help hold items in place while you solder.

Make a quick jig by taking two strips of aluminum, wood, or similar rigid material, that are about 1/3 the height of your cells and a few inches longer than your pack. Put one piece along each side of the cells and secure with an elastic around the end of the bars. Your cells are held together in a tight cell sandwich and ready to solder!



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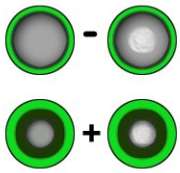
Putting it all together

Lay out all the parts and tools you'll be using on your heat resistant work table so you won't have to get up for anything. Make sure each cell is fully discharged to reduce the chance of an accidental short during the assembly process causing serious damage or harm. Make sure you follow all safety precautions for soldering tools, equipment, and chemical based batteries.

Cell Preparation



1. Use the sand paper or emery cloth to lightly scuff the positive and negative contacts. Don't go overboard. You are just looking to remove dirt and tarnish leaving a nice clean surface ready to accept solder. An easy way is to wrap the sandpaper around the eraser part of a pencil and use it in a circular motion.
2. If you are using naked cells double shrink wrap each cell following the product's directions. If desired, you can also add an additional shrink wrap layer to cells that come covered for additional protection.

Cell Bonding

1. Take the prepared cells and line them up as you want them in the final pack along a straight edge guide or in a battery jig. Make sure your connections will make the current flow in the correct direction for you pack. For example in a side-by-side pack, each cell in the pack will be turned in the opposite direction from the cell it is next to. So looking down the top you should see you +, -, +, -, +, - and so the bottom should be -, +, -, +, -, +.
2. After making sure that all the cells are in the right order you can start gluing the cells together. Take one cell, apply a thin bead of adhesive along one side and press another cell against it to glue the two together. Continue, making sure they stay aligned, until all the cells are glued together. Allow the adhesive to cure according to the product directions.

Soldering the Pack

1. Plug in your soldering iron and make sure you have a clean wet sponge handy. Wipe the hot tip on the wet sponge to clean it. Apply some solder onto the tip and then wipe it on the sponge to clean it again. Repeat this until the tip of the iron is shiny and bright with a thin coat of solder.
2. Measure and cut your wire to the needed lengths. Remove about 3/16" to 1/4" of the wire insulation from the ends of each wire. Twist the strands of wire tight and tin all. If you are using bars, braid or strips you will need to tin the ends.
3. Next you are going to apply a small drop of solder to the scuffed areas on both the + and - ends of all your cells. Make sure they are set level and upright with easy access to the ends. Apply the hot iron and the solder to the center of the cell at the same time. Feed the solder until you have a small drop adhered to the cell and then immediately pull back the solder and use the iron tip to move it around in a circular motion and spread it out to about ¼ inch diameter. This is a quick process and should only take a second or two to do! Repeat for all remaining cells, both ends.

   ***CAUTION**: If it takes you more than a second or two at this point you can cause damage to the battery and / or reduce its performance*.

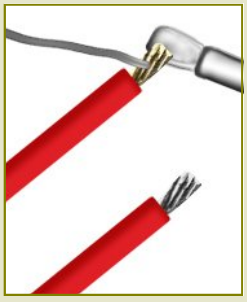
WHAT IS TINNING AND HOW DO YOU DO IT?

Tinning is the process where you apply a thin, even layer of solder to any metal item. Tinning your iron tip makes it ready for soldering and tinning pieces enables you to solder them together faster, easier and achieve a better bond.

To Tin Your Iron Tip:

1. Take your hot soldering iron and wipe the tip on a wet sponge to clean it.
2. Apply some solder onto the tip of it, let the rosin boil off, then wipe it on the wet sponge to clean it again.
3. Repeat this until the tip of the iron is shiny and bright with a thin coat of solder.

To Tin Wires and Other Objects:



1. With a hot, clean tip heat the area of the wire to be tinned by placing the tip of the soldering iron along the side of the exposed strands.
2. Apply solder to the wire, not to the soldering iron tip! When the wire end gets hot enough, the solder will melt and capillary action will draw the molten solder up into the strands.
3. The same basic process is used to tin connecting bars, braid, strips, etc. The goal is to apply a thin, even coat of solder.

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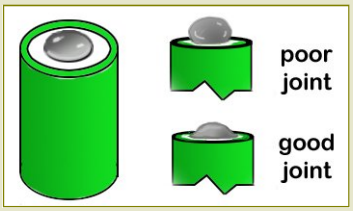
4. Now connect your batteries together using your chosen connection type. Use pliers or tweezers to hold the connector in place. Hold the tinned connector in place and then take your iron tip and press it on top of one end of the connecter and into the solder on the cell. Once the solder melts, it will bond the connector to the cell. Apply additional solder if needed to form a strong joint. Remove the iron tip and allow the solder to solidify and cool completely before moving on to the next connection and cell. Repeat the process for all the cells making sure your connections follow your original plan.



As the solder melts, it should form a very shallow bump, kind of like what a mosquito bite looks like. It should not look like a ball, a drop, or a bead. After the solder has fully melted you can use the soldering iron to slowly spread it around a bit, but don't over do it.

***CAUTION**: it should take between 5 - 7 seconds to solder each joint. Any longer and you risk damaging or overheating the battery*.

5. Inspect all the joints carefully. You should have smooth solder seams at all your connections without lumps, beads, or little balls of solder. The ends of the connectors should appear melted into the battery. If you are unsure about the connection, or if you think it needs more solder, you can reheat the connection and apply some more solder (and flux if needed) to it.
6. Since heat is very bad for a battery don't repeatedly rework connections or keep the iron on the battery for more than a few seconds. If the solder doesn't seem to be melting fast enough, make sure the tip is clean and that your iron is operating properly.

Wire Connections & Finishing

1. If you are going to hard wire the battery to your ESC, all you have to do is solder on connectors at either end of your pack. One will be the positive and the other will be the negative and then you'll just solder the wires from your ESC to the correct connector.
2. A more common option is to solder on some lead wires which can be soldered to a plug end or directly wired to your ESC. Follow the same guidelines as above. You will strip off about ¼" of the protective plastic sheath and then flux and tin the ends and then attach to the appropriate ends of your battery pack following the same procedure used above for connecting the cells. Then attach these leads to the plug (if being used).
3. Wrap your cells in shrink wrap to secure them and cover the connections to finish off the project. Follow the products instructions.
4. You need to test that the pack can safely take a charge. When charging cells for the first time, make sure to charge at a trickle charge rate! This allows the cells to equal out better than if you were to blast them with a quick charge. It is a good idea to cycle your new pack's cells like this a couple of times prior to any quick charging.

Helpful Tips and Things to Remember

- Practice on old cells first! It will take building a couple of packs before you get the process down. If you don't have any check with local places that accept rechargeable batteries for recycling.
- Invest in an iron with sufficient wattage and a large enough tip. It sounds backward; applying more heat when you're trying to avoid cooking the cells, but isn't. More heat means the metal will have a harder time spreading it, you'll get the solder to stick on the cell faster, and the less likely you'll be to damage the battery. The goal is to have the iron contacting the cell for the shortest time possible!

NOTE: Soldering guns are a poor choice for constructing battery packs because they have very small tips and cool down too much, forcing you to hold them in contact for far too long to achieve a good solder connection.

- Clean and tin the soldering iron tip often. A clean tip maximizes heat transfer allowing you to make your connections faster.
- Always tin the parts that are to be joined.
- Never apply solder to the iron and then try to use the soldering iron like a brush to "paint" the solder onto the battery; it won't hold and makes a poor connection. You want the solder to melt against the battery and secure your connector for proper electrical flow.

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- When using braided wire, twist the wires together before soldering for a good mechanical connection.
- Do not over tin the wires or apply too much solder to the connection.
- Take a pair of needle nose pliers and wrap a rubber band around the handles tight enough to hold the jaws shut. Then you can pry the jaws open, insert a connector, and let it go. The rubber band will hold the jaws shut keeping the connector firmly in place and make it easier to hold while working.
- Always insulate your soldered connections to prevent shorting.
- Always be ready for the worst, no matter how unlikely it might be that it happens. Ideally you should do the soldering in a well ventilated area on a heat resistant surface (stone is good, wood is not) and with no flammable materials nearby. Make sure you have the proper safety equipment at hand and ready.

> Lithium polymer (LiPo) cells are not metal-cased, so you can't solder to them using this method.

Glossary of Terms

Acid Core Solder: Solder with an acid flux in the center. It is used for soldering more difficult metals, such as galvanized iron. Soldered surfaces should be washed after each soldering to remove the corrosive effect of the acid.

Ampere: A unit of measure of the rate of electron flow or current in an electrical conductor. One ampere of current represents one coulomb of electrical charge (6.24 x 1018 charge carriers) moving past a specific point in one second.

AWG: American wire gauge (AWG) is a standardized wire gauge system used since 1857 predominantly in the United States for the diameters of round, solid, nonferrous (not iron based), electrically conducting wire.

Battery Bar: Strips of solid metal and some times braided wire strands that are used to connect and carry the current between cells in a battery pack.

Battery Pack: A group of any number of (preferably) identical batteries or individual battery cells configured to work together to deliver a desired voltage or power density.

Brick Pack: When cells in a battery pack are arranged side-by-side creating a cube or "brick". Also called side-by-side packs.

Cell: A single battery in a battery pack.

Current: Essentially how fast electrons are moving in a circuit. It is measured in amperes (amps). Current (Amps) = Potential (Volts) / Resistance (Ohms)

Desoldering Braid: See soldering wick.

Desoldering Wick: See soldering wick.

ESC: Short for Electronic Speed Control. It sends power to the motor, and tells how much power to give it, in relation to trigger movement on the remote.

Flux: A chemical cleaning agent which facilitates soldering, brazing, and welding by removing oxidation from the metals being joined.

Jig: A devise used to hold the correct positional relationship between a piece of work and the tool or between parts of work during assembly.

LiPo: Short for lithium polymer, a lithium based rechargeable battery that uses a polymer case allowing it to be lighter and specifically shaped for its application and offer a very high capacity for its weight. They need to be carefully monitored during charging as overcharging or charging a physically damaged or over discharged cell can be a potential fire hazard.

Nicad, NiCd: Short for Nickel Cadmium, a type of rechargeable battery used for RC products. They are relatively inexpensive. They need to be fully discharged after each and every use. If not, they will not discharge to their full potential on subsequent discharge cycles.

NiMH, NI-MH: Short for Nickel-Metal Hydride, a type of rechargeable battery used for RC products. They have a significantly higher energy potential (capacity) in cells approximately the same size and weight of comparable NiCd cells and they don't require complete discharge between charging. They were developed as an alternative to Nickel Cadmium cells.

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Milliampere-hour: Designated as mAh. It is one-thousandth of an ampere and used to describe how much electrical charge a particular battery will hold, especially for small batteries.

Multi-Meter: An electronic measuring instrument that combines several measurement functions in one unit. A typical multi-meter may include the ability to measure voltage, current and resistance. Also known as a volt/ohm meter or VOM.

Parallel: A configuration for connecting cells in a battery pack where the positive terminal of one cell is connected to the positive terminal of another, and negative terminal of one cell to the negative of another.

Polarity: Refers to the direction of electron flow. The polarity in cells is indicated by a positive (+) end (terminal) and a negative (-) end. Electrons move from negative to positive.

Resistance: Describes how easily electricity flows through a material. Where resistance is high more effort is needed. A smaller-diameter electrical wire has more resistance to electrical flow than a larger-diameter wire. It's measured in units called ohms.

Rosin Core Solder: Solder with a rosin flux in the center. Used for soldering electrical wiring.

Series: A configuration for connecting cells in a battery pack where the positive terminal of one cell is wired to the negative terminal of the next cell, which is wired to the positive terminal of the next cell, and so forth.

Soldering Wick: Usually found as a roll of fine, braided 18 to 42 AWG wire of high conductivity electrical copper, which has been treated with a rosin solder flux. In RC it is an option used to connect cells in a pack. It is also used for removing solder from any solder joint. Also called desoldering wick or desoldering braid.

Stick Pack: When cells in a battery pack are connected in a line, positive to negative like batteries in a flashlight. Also called shotgun packs.

Tinning: The process of coating a metal with a thin layer of solder. Tinning is often done to make attaching components and wires easier and quicker.

Voltage: The rate at which energy is drawn from a source that produces a flow of electricity in a circuit; the measurement of electrical pressure.

Watts: Watts is a measure of the amount of electricity being used; a rate of electrical power consumption. The formula for determining how many watts an electrical circuit can carry or how many watts an electrical device will require is Watts = Volts x Amps.

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