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Electronics Assembly

Kate Thompson

Electronic devices for the purpose of this document are components or collections of components that require and/or modify electricity to perform their function. Motors and solenoids turn electric power into mechanical motion. Electronic components like resistors, capacitors and inductors modify the voltage or the current of electricity as it passes through them to enable sensors, control systems and other devices to function. But in order to combine components into devices and devices into more complex systems (like robots), the components and devices must share both a mechanical connection and an electrical connection.

The mechanical connection is necessary to keep components in place and in contact. This connection should be strong and prevent the device or system from damage in case of accidental bumping, shaking, tipping, or dropping. The electrical connection is necessary to produce a path of very low resistance, so the electricity may pass through all of the components unimpeded and with tolerable losses. It is sometimes possible to create the mechanical and electrical connection using the same mechanism, but the mechanical strength of the bond is often very low in these cases and the devices could be very fragile. Whenever possible, use a separate method to create the two connections to increase strength and robustness of the design.

There are a number of methods that have been developed to allow the assembly of electronic components including soldering, crimping, and off-the-shelf electrical quick connect devices.

1.1 Wire

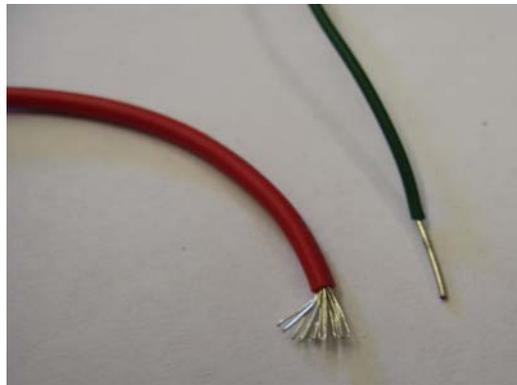
Although many electronic components are designed to allow them to interface directly with other components, many still require wire to carry the electricity between devices.

1.1.1 Wire

Electrical wire is just flexible thread or slender rod made from a metal or metal alloy with very low electrical resistivity (usually copper).

1.1.1.1 Stranded Vs. Solid Core

Wire made up of many strands of thread twisted around each other is called "stranded" wire, whereas wire made up of a solid rod of metal is referred to as "solid core" wire. For most applications, it doesn't matter which type of wire you choose. Stranded wire is more flexible and much more resistant to fatigue than solid core but the ends tend to fray if not taped or soldered together. Stranded wire should be used whenever the wire will be moved around a lot and especially when the components will be subjected to vibration or cyclical loading. Solid core will have a slightly lower resistivity over long distances and does not fray so it can be more convenient to use for bread board work but can be more expensive than stranded wire.



1.1.1.2 Wire Gauge

The size of wire is specified based on "gauge" as opposed to diameter. In general, the larger the gauge, the smaller the wire diameter. To calculate the exact diameter for a given gauge of wire, use the following equation:

$$0.3248 * \exp(0.1159 * \text{gauge}) = \text{wire diameter (inch)}$$

This formula works for any gauge from (0 to 40) or larger. For 00 gauge enter -1, for 000 enter -2 and 0000 -3.

Smaller gauge (larger diameter) wires have less resistance per unit length than smaller gauge wires. Since they dissipate less energy, they generate less heat per unit length and can carry more power. However, they are larger, heavier, less flexible and more expensive than larger gauge (smaller diameter) wires. For electronics applications (as opposed to power lines over miles) it is best to use the smallest wire that can carry the electrical load you require.

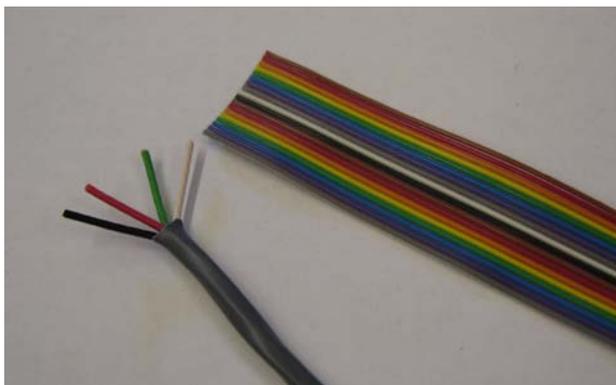
1.1.1.3 Insulation

Most electrical wire is coated with some form of insulation (often a thin plastic) to prevent accidental shorting when there is electricity flowing in the wire. To gain access to the wire inside to create electrical connections, you must remove this coating or "strip" the wire. Once the electrical connection is made, you must add a new layer of insulation to the connection to prevent future shorts. This can be done by wrapping the exposed wire in electrical tape. You can also place a piece of heat shrink tubing over the exposed wires and then use a heat gun (basically an overpowered, very hot hair dryer) to cause the tubing to shrink around the wires and protect them.

Potting the wires in hot glue is NOT recommended. Remember that as electricity runs through the wires, energy will be dissipated in the form of heat. Since hot glue has a very low melting temperature, it's possible that the wires will melt the glue around them, making a mess and removing the insulation.

1.1.1.4 Wires vs. Cable

When multiple insulated wires are bundled together inside a second set of insulation, the individual wires are referred to as "leads" and the collection of wires is referred to as "cable." Cables can be round or flat (as in computer ribbon cable).



1.1.2 Tools

Electrical wiring really only requires two tools: wire cutters to cut the wire and wire strippers to remove the insulation coating from the wire.

1.1.2.1 Wire Cutters

Wire cutters are pretty much any tool that can cut through metal electrical wire without blunting the cutting blades. Regular scissors won't work but a decent pair of wire cutters should only cost a few dollars and are easy to find at your favorite local or online electronics store.



1.1.2.2 Wire Strippers

Wire strippers are a tool that bites into the insulation on a wire, but not through the wire itself. As the user pulls the strippers in the direction of the wire tip, the insulation is dragged with it, exposing a short length of wire. Some wire strippers are fairly simple and the user must take care not to cut through the wire. Other wire strippers have a series of sized holes for stripping different sizes of wire. Finally, mechanical wire strippers allow the user to strip a wire with very little effort but simply squeezing the handle.



1.1.3 Hazards and Safety Information

There are relatively few hazards associated with cutting and stripping wires. It is possible to accidentally cut yourself with the wire cutters or on sharp portions of exposed wire, to bang you hand while pulling off wire insulation with wire strippers, and to hit yourself or others (especially in the eye or face) with flying bits of wire or insulation. As a result, eye protection (i.e. safety glasses or goggles) is required when working with wires.

1.2 Soldering

Soldering is a manufacturing process by which two metal surfaces are joined by applying a third molten metal at the interface. (The metal of the two original surfaces does not melt.) Soldering is similar to brazing but is done at much lower temperatures. Although the term soldering can be applied to other applications, including joining and sealing pipes, for this application we will only discuss soldering for electrical components.

1.2.1 Soldering Tools

1.2.1.1 Solder

Solder is a metal alloy that has a low melting point and good electric conductivity. It often contains a combination of one or more of the following metals: lead, silver, tin and antimony. It also often contains trace amounts of other metals. The melting point of solder can range from 180 C to 450 C depending on the alloy used. The electrical resistivity is usually on the order of $1e-5$ ohms - cm. (In comparison, the electrical resistivity of copper is on the order of $2e-6$ ohms - cm and the electrical resistivity of plastic is on the order of $1e15$ ohms - cm.)

The tensile strength of solder is generally on the order of 20 - 60 MPa, which is comparable to the strength of plastics and an order of magnitude lower than the strength of other metals like steel. However, there are high strength solders that are up to 100x stronger for special applications.

Lead free solders are available for use and contain tin, copper, silver and other metals in varying amounts. Lead free solders have higher melting points than their counterparts and may produce mechanically weaker solder joints depending.



1.2.1.2 Flux

Soldering flux is a gooey substance that contains an acid that cleans the surfaces to be soldered by dissolving oxides that have formed on those surfaces. This allows the molten solder to better wet the surfaces and create a stronger solder joint. Flux also dissolves oxide off of the liquid solder, making it less crusty and more shiny. Since the flux cannot remove significant corrosion, you should pre-clean any badly oxidized surfaces with an abrasive pad or clean steel wool before applying the flux. For convenience, solder is often manufactured as a hollow tube and filled with flux but it can also be purchased separately.

There are three main types of flux: rosin flux, acid flux and water soluble flux. Rosin based fluxes contain organic acids in a rosin matrix. Additional compounds which decompose at high temperature to form additional acids (like ammonia or hydrochloric acid) may also be added. The acids are strong enough to remove oxides from metals like copper, tin, lead and silver but not from steel, iron, chrome or aluminum. Rosin based fluxes leave behind small amounts of plastic-like solids after use which are not very corrosive and can be removed with solvents. Acid fluxes contain a stronger acid than the acid present in rosin fluxes so it is able to remove oxides from more difficult metals like steel, however the residue is also corrosive so it should be removed immediately and should not be used on electronic components. Water soluble flux is a type of flux whose residue is water soluble.



1.2.1.3 Soldering Irons

A soldering iron is basically a heating element contained inside of an insulated handle connected to a hot metal tip. The tip is used to heat the solder and the surfaces to be joined. The tips are interchangeable, allowing different shaped tips to be used for different applications and damaged tips to be replaced. Soldering irons are typically electrically powered, but they can also be cordless or butane powered. Once plugged in or turned on, a soldering iron is always hot.

Soldering irons often come with a stand to hold the hot iron. This prevents the iron from rolling around or burning the work surface. The stand may have a sponge for cleaning the tip. Some soldering irons for professional use come as part of a soldering station, which allows the temperature of the tip to be adjusted.

A cheap soldering iron with a low quality tip won't solder very well for very long. Consider investing in a good quality iron or soldering station.



1.2.1.4 Soldering Guns

Soldering guns are similar to soldering irons except the tip is only heated when the trigger is pulled. A few seconds later the tip is hot enough to use. When the trigger is released, the tip cools again. Because the tip is only hot when in use, it is a slightly safer tool. However, the heat regulation in soldering guns is not very good and the tip is larger and more difficult to use for detail work.

1.2.2 Soldering Procedure

1.2.2.1 General Soldering Technique

The key to soldering is properly heating the surfaces you want to join. If done correctly, the solder wets the surfaces and then flows over the surfaces to be joined, thus a wetted surface is joined over a much larger area, increasing both mechanical strength and electrical conductivity.

Step 1: Tinning the Iron:

Wetting the surface of a large conducting material (heat sink) requires efficient transfer of heat from the soldering iron to the surface. Simply touching the surface with the tip of the soldering iron is often not good enough. Before touching the surfaces to be joined, melt a glob of solder on the tip. This is called tinning the iron and will make the heat transfer from the tip to the surface more efficient.

Step 2: Heating the Surface(s):

The second step is to heat the surfaces to be soldered. The surfaces must be hot enough to melt the solder and keep it melted long enough for the solder to flow and make a good joint. If the solder is melted onto a cold surface, it will freeze immediately and form a very weak joint that will fail quickly.

(Note: Be careful not to heat the surfaces too long. Some sensitive electronic components can be damaged or melted if subjected to a soldering iron for too long.)

Step 3: Applying the Solder:

Once the surfaces are heated, touch the solder to the hot surfaces near (but not touching) the soldering iron. It should melt and flow. Once a good joint has been created, remove the iron and let the solder cool. The joint should be shiny and smooth and not blob-shaped. (A blob shape indicates a cold solder joint that did not flow.)

Step 4: Cleaning the Iron

In general, clean the tip of the iron by wiping it off on a wet sponge before creating a solder joint but not after. Before turning off your iron between sessions, place a large glob of solder on the tip. This will help protect the tip from oxidation and thermal strains during cooling.

Exercise 1: Soldering to Electrical Leads

Leads are small metal tabs, usually with a hole through the center, on electronic devices like motors, solenoids, and switches for attaching wire or other components. This is one of the most common types of soldering you will do. In this example, we use a disposable solder lug instead a lead attached to an expensive piece of equipment. To solder a wire to an electrical lead:

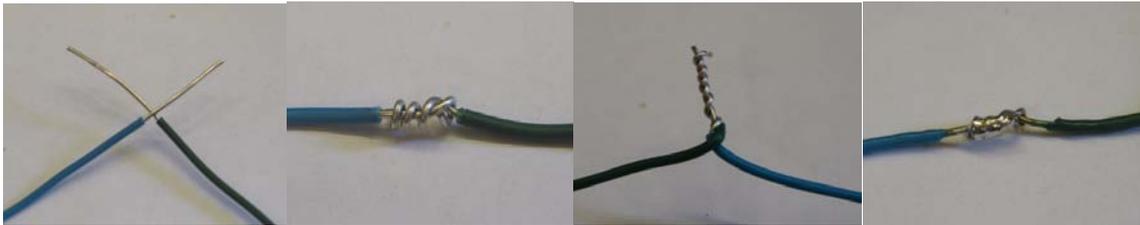
- Strip the wire.
- Slip wire through hole in lead and wrap around the lead, horizontally.
- Pinch the wire into place with pliers if it doesn't want to wrap properly.
- Solder. Tin the tip of the iron and touch it to the lead. Touch the solder to the other side of the lead. Try to keep the iron as far away as possible from any plastic packaging present.
- Make sure that the solder flows. The joint is good when you have solder on both sides of the lead and is smooth and evenly distributed over the surface. The solder should also flow through the hole.
- Don't overheat electronic components. Many electronic components, such as sensors and switches, can be damaged or even destroyed by leaving the soldering iron in contact with them too long. Leave the iron in place only long enough to cause the solder to flow, but no longer.



Exercise 2: Soldering Wires Together

Wires often need to be spliced together to connect components or to repair damaged wires. Whenever you splice wires, the mechanical strength of the splice is as important as the electrical connection. To create a good splice:

- Strip both wires more than 0.5".
- Cross them in an "x" shape.
- Wrap them around each other. Wrap the top wire down and the bottom wire up, and continue wrapping until the splice is complete. Two methods for wrapping are shown below.
- Solder the wrapped wires being careful not to melt too much of the insulation and not to burn your fingers.
- When they are cool, wrap with electrical tape, shrink wrap, or other form of insulation.

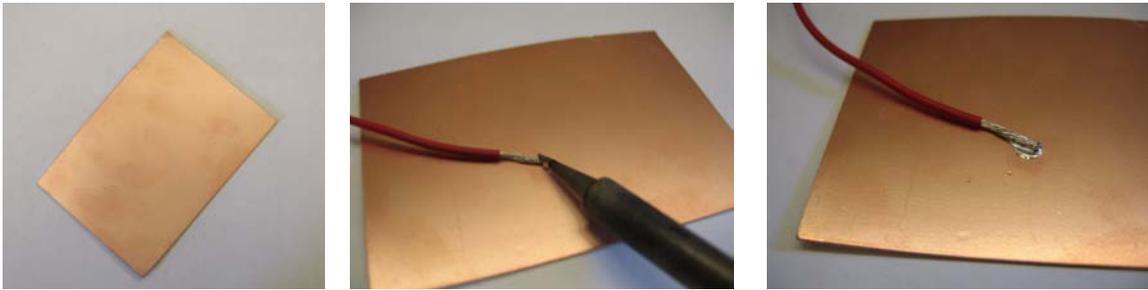


Exercise 3: Soldering a Wire to Copper Clad

Soldering a wire to a piece of copper clad plate is one of the most difficult and least common soldering operations that you will perform. This is because the copper clad plate will conduct the heat from the iron away from the solder joint very quickly and it is difficult to get the solder to flow. If you can perform this soldering operation, you should be able to solder anything together. To solder a wire to a piece of copper clad:

- Cut a small piece copper clad plate.
- Strip the wire (stranded will work best).
- Tin the tip of the iron.
- Place the iron tip on top of the stripped wire and press hard, spreading out the strands a bit if necessary.
- Feed the solder into the wire / iron interface and wait for the solder to flow.
- If the solder will not flow after a few moment, clean and re-tin the iron and repeat.

The solder on the tip of the iron will oxidize after a few moments and will not adhere properly to the copper after this occurs. You should not be able to pull the wire off of the copper clad plate once the solder joint cools.



1.2.3 Hazards and Safety Information

Solder and the surface it touches is very hot and can remain very hot for a few moments after a solder joint is complete. Touching the solder, the iron or the heated surfaces can cause serious burns. When in doubt, use a tool (like a pair of pliers) instead of your fingers to manipulate recently heated surfaces.

Solder contains lead which is hazardous to your health and can cause problems including nerve, muscle, brain and kidney damage. During and after soldering, keep your hands away from food and out of your mouth until after you've washed them thoroughly.

The fumes from the solder flux can also be very hazardous to your health. Try to minimize exposure to fumes during soldering by soldering in a well ventilated and minimizing time spent soldering.

1.3 Desoldering

Occasionally, soldered joints must be taken apart. This may be necessary to replace a damaged component, to repair a bad solder joint or for another reason.

Before attempting to desolder a joint, determine what components are critical to the circuit and what components can be sacrificed. For example, wire can often be removed and replaced with another piece of wire, but the lead on a motor cannot be replaced and must be protected at all costs. After determining which components must be protected,

use a pair of wire cutters to remove excess solder and wire from the system. You may then use either a desoldering pump or desoldering braid to remove the remained of the excess solder from the important surfaces.

1.3.1 Desoldering Pump

A desoldering pump is used when large amounts of solder are present in the electronic system. Desoldering pumps are hollow cylinders with a plastic nozzle at one end, a button on the side, and a spring-loaded piston at the other end. When the piston is depressed fully, it clicks into place and creates a vacuum within the central chamber. When the button is pressed, the piston is released, sucking any material near the nozzle into the chamber.



To use the desoldering pump:

- Depress the piston until it clicks into place.
- Use a soldering iron to heat the solder on the joint until it melts.
- Quickly remove the soldering iron and place the nozzle of the desoldering pump on or near the solder and press the button. The liquid solder should be sucked into the central chamber where it will cool and fall out again. Do this step very quickly, or the solder may solidify again before the pump can be put into place.
- The pump removes the bulk of the solder, but a thin coating will remain.
- Be careful not to melt the tip of the desoldering pump when it is near the soldering iron.

While the desoldering pump removes most of the excess solder, wires and other electronic components often remain joined by a small amount of solder (such as wire still wrapped around a motor

To remove wire from a motor lead:

- Use a soldering iron to heat the joint until the solder is melted.
- Using a pair of needle nose pliers, gently tug on the wire until it comes loose. You may need to tug on the wire while still in contact with the soldering iron or to reapply the soldering iron after the solder solidifies.

- Alternately using wire cutters to remove excess wire and needle nose pliers to free wire wrapped around the lead usually succeeds in removing the solder joint without damaging the lead.

1.3.2 Desoldering Braid

Solder adheres better to some surfaces more than others. Desoldering braid is a flat woven band of copper that is coated in flux. The solder prefers to adhere to the braid more than most other material and small amounts of solder will transfer to the braid. It is most often employed to remove a residual coating of solder once wires and other elements of the solder joint have been removed.

To use the desoldering braid:

- Place a clean section of braid on the solder joint and heat with a soldering iron. A small amount of solder should be transferred from the joint to the braid. Repeat as necessary.



Exercise 4: Desoldering Wire from Copper Clad

Desoldering a wire from a piece of copper clad plate is one of the easiest desoldering operations. This is because the only mechanical connection between the wire and the plate is through the solder, so when the solder is removed the wire is released. To desolder a wire from a piece of copper clad plate:

- Prime the desoldering pump by depressing the piston until it clicks into place.
- Place the soldering iron on the soldered portion of the wire and heat the joint.
- When the joint is warm and the solder has begun to flow, quickly remove the iron from the joint and place the tip of the desoldering pump near the joint and press the button. The bulk of the solder should have been removed.
- Place a fresh piece of desoldering braid on the wire/plate joint and place the iron on top of the desoldering braid.

- Heat the braid/wire/plate joint with the soldering iron to remove any remaining solder and release the wire.

