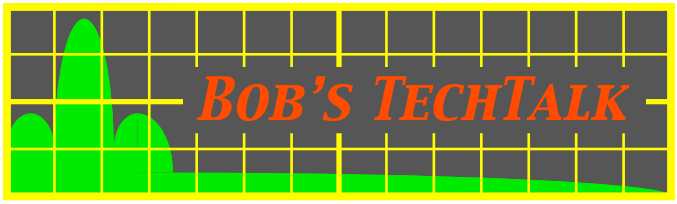


Number 45
by Bob Eckweiler, AF6C

Soldering - Basic Information
by Bob Eckweiler, AF6C

Introduction
Soldering is a process of using a low melting temperature metal alloy to join two pieces of metal together. The process is also often used for coating metals. Plumbing and stained glass assembly are just a few of the many places where soldering is employed.. Soldering is used heavily in the electronic industry to connect circuits together. This white paper focuses on the process of soldering as it relates to the electronic hobbyist and ham operator.

Soldering involves heating the components to be joined as well the solder. Assuming the items to be joined are clean, when the area of the connection reaches the correct temperature the solder melts and binds the metal parts to be joined together when it cools. The success of soldering depends on cleanliness, proper temperature and keeping the connection still while the solder cools.

Solder Types
Solder comes in many alloys, integral flux types, and sizes. A quick survey listed over 150 different types of solder alloys, on top of that solder often contains one of several types of flux. We'll discuss flux in a bit. Solder also comes in different shapes and sizes. Most common is the wire shape, though sheet, bar and even brick shapes are available for specific uses.

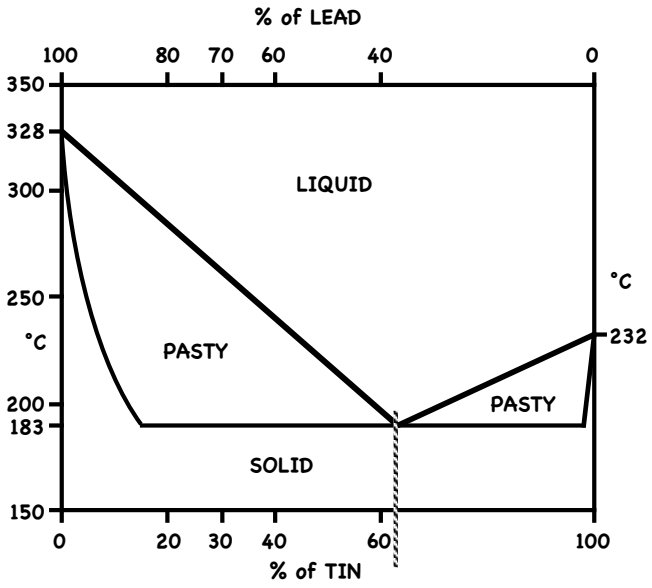
In hobby electronics you will mostly be using wire solder; however even wire solder comes in numerous diameters. Wire solder can be found diameters from 0.125" (1/8") down to 0.015" and probably smaller. The largest solder you will probably use for electronic soldering is 0.062" (1/16"). This is good for chassis terminal work and "UHF" and "N" type coaxial connectors. Solder with a diameter of 0.040" or 0.031" (1/32") is normally used for through-hole circuit board hand assembly and can be used in place of the larger diameter solder if the larger size is not available. Just realize that you have to use a longer length of solder to get the same volume and sometimes the extra movement can add a bit of difficulty to feeding the solder. The small 0.022" (and even smaller diameters) are used for fine work and hand soldering of surface mounted components.

For many years the most common solder type for electronics contained an alloy of tin and lead (sometimes with traces of silver and or copper added). With the recent environmental movement, lead in solder has become less popular and lead-free solder is becoming more of a standard. Lead is a known heavy metal poison and while exposure during soldering can be controlled, the scrapped electronics that is ending up in our landfills contains a lot of solder that can leach lead into the soil. Many newer electronic components are now marked as RoHS (Restriction of Hazardous Substances) in part indicating the use of lead-free solder.

Tin-lead solder however has a lot of advantages for general electronic work for the hobbyist. For electronics it is usually found in a ratio of 60:40 - often designated SN60, or 63:37 - often designated SN63 The two numbers between the ratio colon are the percent of tin to lead. SN63 is ideal as it is an **eutectic** mixture (we'll discuss eutectic in a separate paragraph). SN60 is close enough to the eutectic point to work well, is less expensive and more readily available. Until lead-free solder came on the scene SN60 was the solder used for mostly all common electronic soldering.

Eutectic Point of Solder:
So, what is the eutectic point? Pure tin melts at 232°C; pure lead melts at 328°C. When you

combine them the melting point of the alloy is lower than either element and varies with the ratio of the two. At one particular ratio the alloy melts at it's lowest temperature. This is the eutectic point. For tin-lead solder that point is 63% tin and 37% lead and has a melting point of 183°C. At this point the alloy goes from solid directly into liquid. At all other mixtures of tin and lead the solder goes through a stage of being "pasty" where the paste is one element being liquid and the other being solid particles within the liquid. This is illustrated in the following graph with the eutectic point marked by the broken line:



EUTECTIC GRAPH FOR TIN - LEAD SOLDER

If you look at the point for 60:40 tin-lead solder (just to the left of the eutectic point) you'll see there is a small temperature range where the solder is pasty. When you solder you want to be sure that the solder and the area it touches is above this pasty temperature zone. You also want to be sure that when the solder joint is cooling that the parts are held steady while the solder cools through this pasty zone. SN60 solder reaches its liquid state at 188°C so the pasty point is only 5°C wide and generally easily managed.

Solder can also contain other elements; trace amounts of silver and/or copper are sometimes added. These are elements that are dissolved by solder. While the copper in wire being soldered is not a problem, soldering iron tips often contain copper and the solder will erode these tips over time. Also silver bearing solder is sometimes recommended for soldering silver plated components such as plate coils. Silver and copper also add some additional tensile strength to the soldered joint.

As mentioned earlier, lead-free solder is becoming more prevalent in the electronic industry. The solder that comes with the soldering practice kit used in the club's soldering class contains lead-free solder that is 99.3% tin and 0.7% copper. It has a rosin flux core. This variety of solder melts at 227°C, 39°C higher than common SN60 solder. It is an inexpensive solder (actually the word cheap was used in the reference I perused) and is recommended for lead-free wave soldering. I must admit I have never used this type of solder, so I brought SN60 solder for students to used in the class if they desired. I recommend that you do use the SN60 solder, at least while you are new at soldering. You can switch to other RoHS solder after you gain experience. The chart on the next page lists a few common solder types and their specifications. Many of these are available at Radio Shack as well as electronic distributors.

NOTE: ALL GUARANTEES ARE VOIDED AND WE WILL NOT REPAIR OR SERVICE INSTRUMENTS IN WHICH ACID CORE SOLDER OR PASTE FLUXES HAVE BEEN USED. WHEN IN DOUBT ABOUT SOLDER, IT IS RECOMMENDED THAT A NEW ROLL PLAINLY MARKED "ROSIN CORE RADIO SOLDER" BE PURCHASED.

Figure 2: Flux Warning Accompanying Many Heathkits

COMMON TYPES OF ELECTRONIC SOLDER							
CLASS & Designation	**Tin (Sn)**	**Lead (Pb)**	**Silver (Ag)**	**Copper (Cu)**	**Melting Temperature**	**Eutectic**	**Comments**
LEADED:							
SN60	60.0%	40%	(none)	(none)	188° C 370° F	(close)	Most common electronic solder
SN63	63.0%	37%	(none)	(none)	183° C 361° F	Yes	Less common eutectic version of SN60 electronic solder
62/36/2	62.0%	36%	2.0%	(none)	179° C 354° F	Yes	Higher strength tin-lead solder
LEAD FREE:							
99.3/0.7	99.3%		(none)	0.7%	223° C 433° F	Yes	(Inalloy 244) Supplied with soldering kit.
96/4	96.0%		4.0%	(none)	225° C 437° F	No	(ASTM96TS) Radio Shack 64-025
99.2/0.3/0.5	99.2%		0.3%	0.5%	221° C 430° F	No	Radio Shack 64-089 (0.022") or 64-091 (0.05"). Poorly reviewed.

Flux

Flux is a reducing agent used to remove oxidation and help clean the parts to be joined. Flux can come as a liquid or paste and most wire electronic solder includes flux integral to the solder, usually inside one or more "cores" running lengthwise. "Solid wire" solder has no flux.

The two most common types of flux are acid and rosin. Acid core solder is primarily used for plumbing and metal work. It should not be used for electronic soldering. In the 40's and 50's acid core solder was very common and if used in electronic assembly will cause severe damage over a short period of time to the instrument. Most Heathkit manuals included a warning about acid core solder (See Illustration).

Figure 3 - Kester 44

Most electronic solder uses a rosin core flux. New organic fluxes are also sometimes found in some electronic solder. The only solder used in the soldering class was integral rosin flux, commonly referred to Rosin Core Solder .

Flux can also be found as a paste that comes in a small container or a liquid in a glass or plastic bottle. Generally this is not used for general electronic assembly, but certain non-corrosive types can be useful for tinning wires and coaxial cable braid. It can also be used when soldering to a plated steel chassis or working with brass or other metallic solderable shields. Choose the flux paste you intend to use carefully. Some "NoKorode™" solder paste actually is corrosive. Liquid rosin flux can be purchased and is okay to use on electronic circuits, especially if your solder doesn't contain a flux core.

Soldering Guns and Irons

The obvious tool you will need is a soldering iron. They come in many different styles and wattages. Before I recommend one, let's look at what is out there.

One style that is common is the soldering gun. Weller and Wen are two manufacturers. These irons are shaped like a gun, hence their name; they have an internal transformer that converts the AC line voltage into a very low voltage at high current. The current passes through the tip and the resistance in the tip creates a high heat quickly when the trigger is pulled. The tip also cools quickly, making it great for quick jobs. The guns vary in wattage from typically 80 to 250 watts. Some of the Wen models had thermal regulation and tips covering 25 - 100 watts, 100 to 200 watts and 200 to 450 watts. Besides generally being higher wattage than needed for some circuit work, soldering guns can be heavy and hard to get into tight places. A nice feature of the Wen and Weller soldering guns is that the have small light(s) that illuminate your work. Soldering guns can be helpful when soldering large connectors. However unless you find a light low-wattage soldering gun, I'd recommend a pencil soldering iron.

Pencil soldering irons either come as a complete unit or as a modular unit. The complete units sometimes have a replaceable tip, but are fixed as to their wattage. With the modular iron you can choose your handle among various styles, add a heating element for the job you need and select a tip that fits your job. The heating element comes in various wattages and temperature ranges; it screws into the handle and can be changed easily (with tools it can be done while still cooling). Similarly, the tips screw into or on the heater element and can be changed; you have to be careful though to use an anti-seize compound or else the tip can freeze on the element. Tips and elements come as either "thread-on" or "thread-in" depending whether the tip's thread is male or female.

Soldering stations are soldering irons with a built-in temperature sensor and adjustable temperature control. Some have digital readout. They are handy, but not necessary for the casual amateur hobbyist. I'd start with a pencil iron which is always handy because it can be thrown into your toolbox unlike a soldering station.

The iron wattage depends on the job at hand. A 20 - 30 watt iron is good for most circuit board work and point to point wiring. A heavier iron is preferable when soldering chassis ground lugs and heavier wiring, where the heat gets drawn away rapidly by the mass of metal. An iron of 60 to 100 watts works well here.

Soldering Iron Tips:

There are four general types of soldering iron tips, as well as numerous special tips for specific tasks. The four general types are shown in the figure below; their actual names sometimes vary depending on the angle of the taper. Type I includes cone, pencil and tapered needle - tips that come to a point; Type II includes chisel and screwdriver - tips that come to an edge; Type III includes spade - a circular shaft (usually a small diameter) with a diagonal flat cut in the end; Type IV includes pyramid - a circular shaft (usually a large diameter) with three or four diagonal cuts at the end that come to a point.

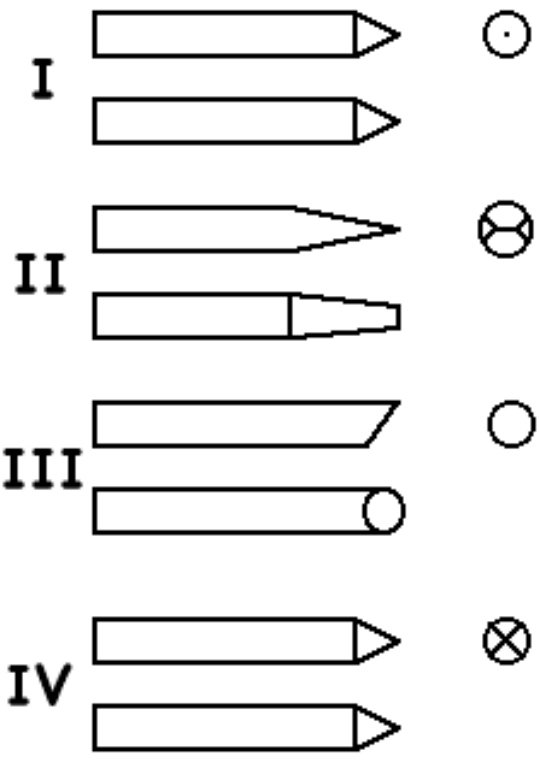


Figure 4: Different Soldering Iron Tips

Tips screw into or onto the heating element (some less expensive irons and many heavy duty irons have tips that slide in and are held by a setscrew). If you want to be able to easily remove the tip it is imperative that you use an anti-seize compound on the threads and tighten the tip only hand tight. I usually leave my tips loose when not being used. Ungar sells a tube of anti-seize compound #8001.

Special tips include ones for unsoldering integrated circuits by heating all the pads at once, and ones with forked tips for bending wire on terminals, just to name a few.

Unsoldering Tools

Part of learning how to solder is learning how to remove soldered components and wires. There are numerous unsoldering tools the electronic hobbyist can use. It can make correcting a mistake or changing a failed component a less difficult task. There are two basic types of tools, one that uses suction or a vacuum to draw molten solder away from the connection, and the other uses a material that is heated at the connection and soaks up the molten solder.

Expensive vacuum unsoldering tools are available, usually as part of a soldering rework station. Various less expensive "solder suckers" either have a suction bulb or a spring loaded vacuum plunger that allows you to use your iron to heat the connection and then, with the solder molten, suck the solder into the solder sucker. These devices have high temperature *Teflon* nozzles the limit the melting of the tip. They need to be cleaned often, as the tip tends to clog and the spring loaded devices need to be taken apart, cleaned and lubricated when they start to show signs of leaking.

A combination solder sucker heating iron is also manufactured. It has a hollow soldering tip that connects to a vacuum bulb. Heating the connection and then releasing the bulb can quickly clean solder from a connection. Radio Shack sells an inexpensive version, Model 64-2060 for $12. It is 45 watts which helps heat the area quickly. Extra tips are available for $2.00.

The best known solder absorbing tool is *Solder Wick* (which is now available under numerous other names). It is a piece of braid that is saturated in rosin flux. You apply it to the connection and heat it just as if you were soldering the braid to the board. The fine braid, aided by the flux, soaks up excess solder into the braid, removing it from the connection. It is most useful on circuit boards. *Solder Wick* comes in various braid widths depending upon the job at hand The soldering practice kit includes a wicking braid, and students will get to practice with it.

Other Tools:

There are numerous other soldering aids available. Heat sinks that clamp on to leads to keep the heat away from the component being soldered; I usually use a hemostat, but often a heat sink is not needed except for soldering critical components.

General Cement used to make a set of five soldering aid tools. These double ended pick-like tools are made of a chromium alloy that solder will not stick to. They have various ends for picking, reaming holes, bending wires, etc. They also have a stainless wire brush and scraper. I've never owned a set of these tools, but there were numerous times when I wished I had them handy. Harbor Freight sells some knockoffs of these tools for a few dollars each. Look in the soldering/welding section.

Anti-Seize was mentioned earlier. You just put a very small dab making sure you totally cover the threads of the tip and tighten the tip hand tight. Next you heat the tip and be sure to tin the tip if it hasn't already been tinned. The anti-seize puts off a lot of smoke when it first heats up so be careful not to breath the vapor.

A very important soldering accessory is a soldering iron holder. Radio Shack sells the model 64-2078 for $9. It comes with a sponge for cleaning the tip. Most irons come with little wire or metal holders that are only the minimum of basic in design. If you solder regularly a holder is a good investment in safety.

Another soldering accessory is a tip cleaner. Many holders have built-in sponges. Weller/ Ungar sells a high temperature plastic sponge holder with special refillable sponges. When I don't have a proper type sponge handy I just use a damp paper towel; it works as well! Ungar, which used to be a big name in soldering tools was bought by Weller and Weller is now a division of Cooper Tools.

Soldering Safety:

Never leave your soldering iron unattended. Alway be sure it is unplugged after use. Keep the work area you are soldering on free of flammable items. A hot unattended soldering iron is a fire waiting to happen! Be extra cautious of the soldering iron cord. Keep the tip away from the cord so you don't melt the insulation.

A soldering iron can give you a nasty burn. Be attentive to where the hot end is at all times. Make sure the cord is free from becoming entangled and is long enough to reach your work easily. If you do get burned, immediately put it under cool running water and leave it there. You want to cool the burned area. If it is a severe burn you should seek medical help. You might want to brush up on burn first aid before you do too much soldering. I'm not a doctor so I'll leave any further discussions to the experts.

If you get too much molten solder on the tip it can drop off. If it lands in your lap or on your thigh it will go through loosely woven clothing and burn you. Also, don't wear nylon or easily melted synthetic clothing when soldering if there is a chance a blob of solder could drop onto any part of your clothing. It is best to keep the work over the table to prevent this. However, sometimes you just can't, so take precautions to keep the molten solder from landing on you should a blob drop from the tip.

Lead is a heavy metal and you want to keep from ingesting lead based solder (probably all other solders too.) After handling solder you should wash your hands. Standard care should be given handling solder. Keep it away from young children. Follow the warnings on the solder and flux packaging.

Figure 5: Weller SP23L with extra tips

When you heat solder it gives off smoke and fumes. Rosin has a pleasant smell to may people, but to some it can cause an allergy. The best solution is to solder in a well ventilated area and to use a fan to keep the smoke from rising right into your face. I use an old surplus "muffin" fan for this. It doesn't need to blow too hard. When you first fire up a soldering iron it often emits a lot of smoke. This is especially true if you have used anti-seize on the tip. Be extra cautious of the smoke when you are first tinning the tip on a new iron. The smoking will stop after a few minutes.

My Soldering Iron Recommendation:

If you are looking for a practical first soldering iron let me recommend the Weller SP23L. It sells for around $17, and is available at ACE Hardware and probably many other hardware stores. It is 20 watts and adequate for most jobs around the shack. The L designation signifies that the iron has a neon light in the handle signifying that it is ON. I've used an older Weller SP-23 (black handle with no light) and it has given me many years of good service. Replacement screw in chisel and point tips are available for the SP-23(L).

73, from AF6C

This article is based on the TechTalk article that originally appeared in the May 2012 issue of "RF", the newsletter of the Orange County Amateur Radio Club - W6ZE.