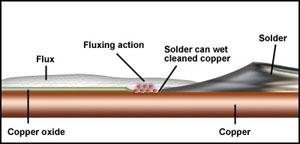
# Flux and Solder Selection

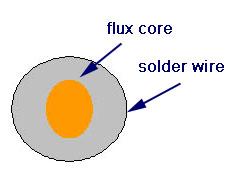
## Objectives

* Describe characteristics of solder.
* Match common solder metals with their properties.
* Match less common solder metals used as alloys with their properties.
* Describe characteristics of solder wire.
* Distinguish between common solder wire compositions.
* Describe characteristics of solder paste.
* Describe characteristics of lead-free solder.
* Explain how flux is used in soldering.
* Describe characteristics of rosin-based flux.
* Describe characteristics of water-soluble flux.
* Describe characteristics of no-clean flux.
* List criteria involved in solder and flux selection.



## What is Solder?

Two materials essential to soldering are **solder** and **flux**, and there are many varieties of these materials from which to choose. Solder is a metal **alloy** that melts during the soldering process and then hardens when cooled to join metallic surfaces. The purpose of using an alloy is to create a material with different **properties** that the original materials may not have, such as a low melting point or a sufficient strength. Various metals are used to create many different types of solder with unique properties.  
  
Solder is available in many forms. The most commonly used forms for hand soldering are **solder wire** and **solder paste**, but solder also comes in bars, tubes, foil, or ribbons, as well as various pre-formed shapes. Figure 1 shows a spool of solder wire. Solder is also available with flux included, which is known as **flux core solder**. Most solder used for electronics fabrication is flux core solder. Figure 2 illustrates flux core solder.  
  
It is essential to select the appropriate materials for each soldering application to avoid damaging sensitive electronic components. This class describes various types of solder and flux used for hand soldering and discusses criteria for their selection.



## Common Solder Metals

There are many different combinations of solder alloys available. The properties of each solder alloy are affected by the type and amount of each metal in the combination. The following are common metals used in soldering, followed by their abbreviation on the **periodic table**:

* **Tin** (Sn), shown in Figure 1, is generally used as the base for solder alloys. Tin is a silvery colored metal that is **ductile**, so it can easily be shaped into various forms. Tin also can be used as a coating to protect materials.
* **Lead** (Pb), shown in Figure 2, is a soft, heavy, gray metal with a low melting point that is also ductile, and is often combined with tin. However, prolonged exposure to lead can present health hazards, so **lead-free solder** is becoming more common.
* **Silver** (Ag), shown in Figure 3, is a soft, white metal that is often used because it is highly **conductive** and creates very strong joints. It is also commonly used when silver is one of the **base metals** in the components being soldered. This is because a silver-based metal can dissolve into the solder too quickly before the solder hardens, which can prevent the joint from forming correctly. Using an alloy that contains silver can prevent this from happening.

Tin, lead, and silver are often combined with other metals to create common soldering alloys.

## Other Common Solder Metals

In addition to tin, lead, and silver, there are other common metals used to create solder alloys:

* **Antimony** (Sb), shown in Figure 1, is a brittle metal that is silvery white in color. It is used as a less expensive alternative to tin, though its **wetting** capability is not as high. Small amounts of antimony are also added to solder to prevent the phenomenon known as **tin pest** in which the crystal structure of tin changes form, causing the tin to become brittle.
* **Copper** (Cu), shown in Figure 2, is a ductile, reddish metal that offers high conductivity and helps to increase a solder’s wetting ability. It can also be used to raise the melting temperature of the solder alloy.
* **Bismuth** (Bi) is a brittle and relatively inexpensive whitish metal that is often used to increase a solder’s wetting ability while lowering its melting point. The fact that bismuth expands when it solidifies makes it well-suited for soldering.
* **Indium** (In), shown in Figure 3, is a silvery gray metal that is soft and ductile. Indium is used to lower the melting point of solder and can be used in large amounts to increase conductivity. However, indium does not have high strength and is also rare, making it expensive to use.

These and other metals can be used in various combinations to create solders with different properties that are suited for particular applications.

## Solder Wire

The most common form of solder used for hand soldering is **solder wire**, shown in Figure 1. This product is generally manufactured as flux core solder, which is a hollow tube of solder that contains flux in the center. Flux core solder is widely used for hand soldering because it saves the soldering technician the extra step of applying flux, and it ensures that the correct amount of flux is applied.  
  
Wire solder is most often sold in one-pound spools, though very fine wire solder is generally sold in half-pound spools. Wire solders with small **diameters** are usually more expensive because they are more costly to produce. When selecting solder wire, you should choose a diameter of solder wire that is comparable in size to the diameter of the joint you are soldering. Solder wire of equal or slightly larger diameter than the joint will cause the solder to fill the joint faster, as well as reduce the amount of solder wire that it takes to complete the joint. In Figure 2, a technician solders with solder wire that is slightly larger than the joint diameter.

## Solder Wire Composition

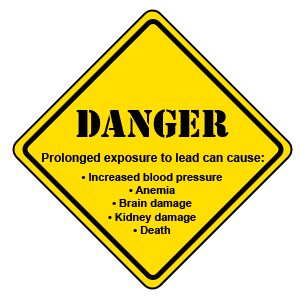
Although solder wire can consist of many different elements, the most frequently used alloys in electronics soldering are made of tin and lead. The most common type of solder wire for electronics is known as **60/40 solder**, which contains 60% tin and 40% lead. This type of solder is preferred because of its quick wetting properties and low **melting point**, which is around 365°F (185°C). Figure 1 shows a spool of 60/40 solder.  
  
Another common variety of solder wire used for electronic applications is **63/37 solder**, composed of 63% tin and 37% lead. This type of solder is also known as **eutectic solder**, which refers to the melting point of the two materials. The slightly increased ratio of tin to lead in eutectic solder allows it to transition from a completely solid state to a completely liquid state.  
  
63/37 solder's melting properties distinguish it from 60/40 solder, which has an intermediate state between liquid and solid form known as a **plastic phase**. When 60/40 solder is in this plastic state, the soldering iron and workpiece must be held perfectly still so as not to cause vibration and disturb the cooling solder, which would damage the joint. However, 63/37 solder is more expensive than 60/40.

## Solder Paste

In addition to solder wire, a product known as **solder paste** is available for hand soldering. Solder paste consists of fine metal particles suspended in a mixture of flux and a paste-like binder. This flux helps protect the solder metal and also increases the solder’s wetting capability.  
  
Solder pastes are available in two different forms. **Dispensable solder pastes** are specifically formulated to be applied with manual dispensing equipment. Packaged in a syringe, the solder flows out through a narrow tip, which lets the operator make small deposits of solder. **Printable solder pastes** are applied to components through a screen or a stencil and are used to apply many small deposits of solder in a short time. Solder paste can be used for large joints such as metal pipes or small joints, such as those on electronic circuit boards. Figure 1 shows a circuit board. Solder paste is also frequently used in automated soldering processes.  
  
In addition to solder wire and paste, solder is available in other shapes such as bars, foil, or pre-formed shapes, which are used for automated soldering. However, solder wire and solder paste are the most common types of solder used for hand soldering.

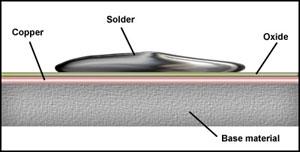
## Lead-Free Solder

The use of **lead-free solder** is becoming increasingly common in industry due to the health hazards of prolonged exposure to lead. Figure 1 lists some of these hazards. The European Union recently outlawed the use of lead in all electronic systems, and lead-free solder is becoming more common in the United States as well. Lead-free solder is defined as any solder that contains less than 0.2% lead by weight.  
  
Because there is no single substitute for lead, lead-free solders must be developed from various alloys. Some of the more commonly used lead-free alloys are **SAC**, composed of tin, silver, and copper, and **SnCu**, composed of tin and copper. While all lead-free solders have significantly higher melting points than lead-based solders, SAC is often preferred for its low melting point.  
  
Unlike smooth and shiny lead-based solders, lead-free solders have a dull and grainy appearance. They also have a lower wetting capability than lead-based solder. Lead-free solders are not suitable for all applications, because some delicate components cannot tolerate the high temperatures needed for lead-free soldering. They are also not used for military or aerospace applications because they tend not to be as strong or reliable as lead-based solder in high-stress environments. Finally, lead-free solders are more likely to develop **tin whiskers**, shown in Figure 2, which can cause devices to short-circuit.



## What is Flux?

Before components can be joined together in the soldering process, they must be cleaned so that the solder can flow evenly and bond to the metal. This is accomplished through the use of **flux**, which removes **oxidation** from the surfaces of the joined metals. Figure 1 shows oxidation preventing solder wetting, while Figure 2 shows flux allowing solder to wet a component. Flux can be applied directly to components with a flux pen, as shown in Figure 3, but most solders used in hand soldering have a flux core. In these types of solders, the flux cleans the joint as the solder melts.  
  
There are two major categories of fluxes used for soldering electronic components: **rosin-based flux** and **water-soluble flux**. Flux strength is measured by its **activity**, which refers to how effectively the flux cleans. Using flux often leaves a **residue**. Depending on the type of flux used and the components being soldered, this residue may need to be removed. Water-soluble flux residues can usually be removed with water. Rosin-based flux residues often require different cleaning agents based on the type of flux used.



## Rosin-Based Flux

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| |  | | --- | | The most commonly used type of flux for electronics soldering is rosin-based flux. Rosin-based fluxes are made from purified pine sap and are available in three activity levels: rosin only (R), rosin mildly activated (RMA), and rosin activated (RA). Figure 1 shows categories of flux.  Rosin-only fluxes are the least active, making them suitable only for surfaces that are already fairly clean. RMA fluxes are more active and leave a small amount of residue on components, as shown in Figure 2. Sometimes this residue can be left on components without causing damage, but in environments with high temperatures or humidity, the residue should be removed.  RA fluxes are the most active and provide the best cleaning, but they leave the most residue. This residue may need to be removed with a flux cleaner before soldering. Generally, RA fluxes are not recommended for use on sensitive electronic components such as circuit boards because their high activity can cause corrosion. RA fluxes are ideal for soldering materials such as **nickel** or **brass**, which are more difficult to solder. | |

## Water-Soluble Flux

Water-soluble fluxes are generally more active than rosin-based fluxes, providing more cleaning action. However, water-soluble fluxes can also leave residue on components that must be removed. The name “water-soluble” indicates that these residues can be removed with water, which is the main advantage of water-soluble flux. This type of flux does not require the use of solvent-based cleaning agents, which often contain chemicals that can be hazardous to health and the environment. Figure 1 shows a flux pen containing water-soluble flux.  
  
Water-soluble fluxes can be either **organic** or **inorganic** in composition, as shown in Figure 2. Organic water-soluble fluxes have high activity and can be used to solder many different types of materials. After soldering, all organic water-soluble flux residue must be removed with warm water because any remaining residue could corrode components, as shown in Figure 3. Corrosion of components can lead to problems such as short circuiting.  
  
Inorganic water soluble fluxes, also known as inorganic acid fluxes, are primarily used with materials that are difficult to solder, such as **stainless steel**. These types of fluxes should not be used with sensitive electronic components because their residues are too corrosive. All inorganic acid flux residues should be removed with warm water to avoid corrosion.

## No-Clean Flux

A recently developed type of flux known as **no-clean flux** (also known as low-residue or low-solids flux) is growing in popularity for use with electronic components. Figure 1 lists characteristics of no-clean flux. No-clean fluxes require little or no cleaning after the components have been soldered since the residues they leave are not corrosive or conductive. Eliminating the cleaning step after soldering can save both time and money, making no-clean flux an attractive option for some companies. Since some types of flux cleaning solvents contain hazardous chemicals, no-clean fluxes can also be beneficial to the environment.  
  
No-clean fluxes are less active than other types of flux and should be used with base metals that are easy to solder. When switching from other types of flux to no-clean flux, tests should be performed to ensure that the change in flux will not negatively affect the components being soldered. Since extensive testing may be required, no-clean flux has not yet become as common in industry as other types of flux.



## Solder and Flux Selection

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| |  | | --- | | When selecting materials for a hand-soldering application, there are many factors to consider. Since flux must be applied before soldering, you must first decide which type of flux you will use. If you are soldering electronic components, you will most likely choose between rosin-based or organic water-soluble flux, though no-clean flux is also an option. Remember that rosin-based flux residues may need to be removed with a solvent-based cleaning agent, while water-soluble flux residues can be removed with water.  If you are not using a separate flux, you will need a solder wire or solder paste that contains the type of flux you require. You will also need to decide if you will be using lead-free solder or a more common alloy such as 60/40 SnPb solder, which has a low melting point and good wetting ability. Figure 1 shows a technician successfully soldering a joint with 60/40 flux core solder wire. Since lead-free solder requires higher melting temperatures, it may not be suitable for all electronics soldering applications. Select the solder alloy with properties that best suit the components you are soldering.  Even if you are not personally responsible for selecting solder and flux at your shop, you should understand how the solder and flux you are using will perform with the components you are soldering. Make sure to consider all elements of solder and flux selection before soldering to avoid damaging the components. | |

## Summary

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| |  | | --- | | Solder is a metal alloy that melts during the soldering process and then hardens when cooled to join metallic surfaces. Tin is generally used as the base for solder alloys. Lead is often combined with tin, but lead-free solder is becoming more common due to health risks of lead. Silver is highly conductive and creates strong joints. Antimony is used as a less expensive alternative to tin. Copper offers high conductivity and helps to increase wetting. Bismuth is also used to increase wetting and lower a solder’s melting point. Indium also lowers the melting point and increases conductivity, but it is expensive.  The most common form of solder used for hand soldering is flux core solder wire. Most solder wire used for electronics is 60/40 solder, though 63/37 solder is also common. Solder paste consists of fine metal particles suspended in a mixture of flux and a paste-like binder. Lead-free solder has a dull and grainy appearance. It also has a lower wetting capability than lead-based solder.  Flux strength is measured by its activity. Water-soluble flux residues can usually be removed with water. Rosin-based flux residues often require different cleaning agents based on the type of flux used. No-clean fluxes require little or no cleaning after the components have been soldered. However, no-clean fluxes require surfaces that are relatively free of contaminants. Make sure to consider all elements of solder and flux selection before soldering to avoid damaging the components. | |