Basic Soldering

Technical Manual

Introduction:

Nearly all components used in modern computer systems are solderless plug-in modules. Computer service and support technicians won't have much use for a soldering iron these days. However, soldering remains to be a difficult to master skill and a technician does need to know how to recognize good soldering from bad. From splicing wires to repairing joints on solder lugs, there are some situations where nothing but a reliable solder connection will do. Soldering is not a new skill either… it's been around for hundreds of years. What's different now is that soldering is being applied to sophisticated electronic circuits rather than the metalwork, tubing, and jewelry of yesteryear. Soldering techniques have also changed to meet the requirements of the ever-shrinking form factors used in emerging technologies.

If you're new to soldering, this lesson will teach you some valuable techniques. Even if you've soldered before, this lesson will help you polish your skills making you an even better technician.

It's important that you read through this section before you do the exercises. You should also refer to this information as you do the exercises if you have any questions. Be sure to study the material very carefully including any reference to safety. Soldering irons can cause serious burns if handled incorrectly.

The overall objectives of this course are to teach you what solder is, how it works, and how to use it. By using these techniques, you will be able to recognize and produce reliable solder connections.

Here's a breakdown of the things you should be able to do after you've finished this lesson:

1. Determine the melting point of solder, given its alloy ratio.
2. Describe how solder mixes with the surfaces being soldered.
3. List the basic advantages of soldering connections.
4. Recognize how "flux" acts with solder and why it is necessary.
5. List the components of the types of solder most commonly used in electronics.
6. List the advantages and disadvantages of common types of soldering equipment.
7. Recognize the causes and characteristics of bad solder connections.
8. Recognize a good connection.
9. Identify the most common mistakes in circuit board soldering.
10. Care and use of soldering irons.
11. Prepare wires to be soldered.
12. Solder wires to terminals.
13. Solder components to a printed circuit board.
14. Use the two most common methods of removing components and repairing solder connections.

Words and Terms You Should Know:

Form Factor
Alloy
High Reliability Soldering
"Eutectic" Solder
Capillary Action
Wetting
Interface
Flux
Rosin
Heat Sink
Solder Wick
Cold Solder Joint
Rosin Joint
Tack Soldering
Thru-Hole Soldering
Surface Mount Technology (SMT)

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Discussion of the Fundamentals:

Why is Reliable Soldering So Important?

Some of the world's most important things depend on sophisticated electronics that require highly reliable soldering. Computerized electronic circuits control the automatic operation of almost everything from the international space station to jet airliners to the computer systems used in modern automobiles. In many cases, lives depend on the safe operation of these electronic circuits.

Courtesy of NASA
Lives may rely on soldering connections.

Modern electronic systems are formed from thousands of components and, in turn, thousands of connections. If even one connection fails, the result may be a loss of money, or even lives.

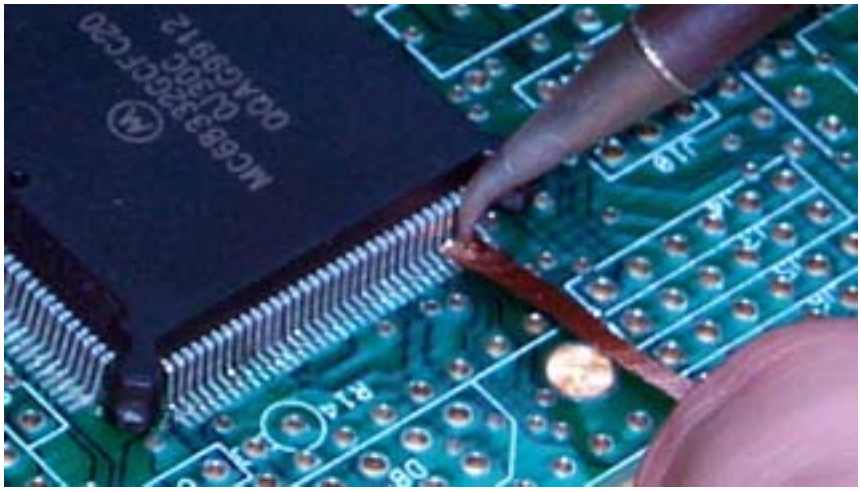
Fortunately, soldering is a remarkably simple, reliable way to avoid failure in those connections. The revolution in miniaturized electronics would not have taken place without soldering.

The composition of solder itself has not changed in hundreds of years. Yet, no matter how far technology has advanced, soldering is still one of the simplest, fastest, least expensive, and most reliable ways of making an electrical connection.

Soldering has two major advantages over other electrical connections:

1. It is an excellent physical connection. Solder fills in the pores of a metal surface, becoming part of the surface. A good solder connection is as strong as the metal surface itself.
2. More importantly, it is an excellent electrical connection. Properly applied solder has virtually no electrical resistance. This is especially important in low voltage applications.

While solder itself has not changed, some soldering applications and techniques have. It's important to note that there are many different levels to the quality of soldering. This course will bring you up to speed on faster, more efficient <u>basic</u> soldering methods.



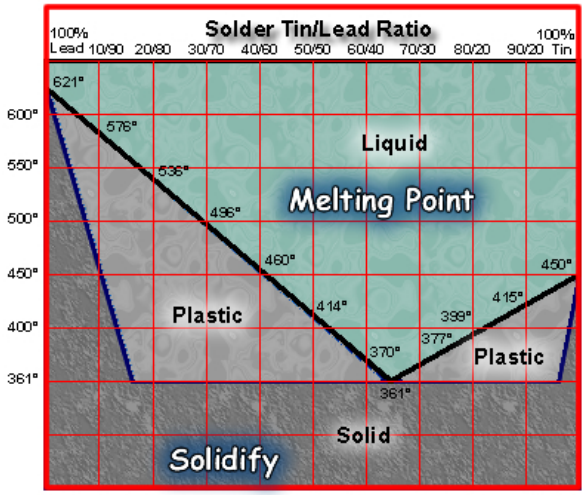
Modern electronics feature thousands of solder connections made by automated machinery, but repaired by hand.

So… What is Solder Anyway?

Solder is an alloy of two different elements: tin and lead. From the earliest times, solder was made from these metals because they both melt at relatively low temperatures and maintain good physical strength.

Pure tin melts at 450° Fahrenheit; pure lead melts at 621° F. However, solder melts at a temperature lower than either of these components. You can actually solder a wire to a piece of tin or lead and the tin or lead surface will not melt.

You can compute the exact melting point of solder if you know the ratio of tin to lead. When you buy solder, the ratio will be shown on a package of solder with numbers such as 60/40 or 50/50. The first number in this ratio will always be tin; the second will always be lead. So, 60/40 solder is 60% tin, 40% lead.



In the table above the vertical scale equals Fahrenheit degrees. The horizontal scale shows the tin/lead ratio, ranging from 100% lead (0/100) to 100% tin (100/0). The melting point line shows the temperatures where various ratios become liquid.

Melted solder is like other liquids because it obeys the laws of "CAPILLARY ACTION." It will flow smoothly to cover every pore of a clean metal surface. Some substances, such as multistrand wire, will break up surface tension so solder can flow up, against gravity, and settle on the surface of each strand.

Let's try an experiment using this chart. Compute the melting point of 50/50 solder. As you can see, the melting point is 414° F. From the chart, you can also see that 40/60 solder melts at 460° F, 70/30 melts at 377° F.

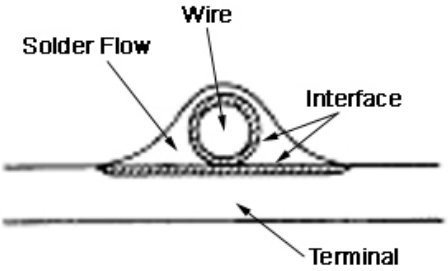
Notice the two triangular areas of the chart labeled "Plastic". This represents a state where solder is semi-liquid and can be moved or molded but it is not fully melted. Solder goes through this state both when heated and when cooling down. It is important to know when solder is in the plastic state because a soldered connection must not be moved while the solder is plastic. I'll explain this in more detail later.

At the bottom of the melting point line you'll find the solder ratio of 63/37. This alloy melts at 361° F, the lowest melting point of any solder. In this area, the chart also shows a narrower "plastic" range. In fact, 63/37 solder actually has no plastic state. It is either a solid or a liquid. 63/37 is called "Eutectic" solder, which is Greek for "easily melted." This is because it melts at the lowest temperature of any solder and it hardens quickly with no plastic state.

Though it has the best properties of any solder, 63/37 is uncommon and expensive, so it is not used much. 60/40 solder is the next best combination, with a low melting point of 374° F and a plastic state range of only 100. For these reasons, 60/40 is the most common alloy of solder used in electronics.

How Does Solder Work?

Some people think that soldering is a form of welding or gluing… It's not. In welding, two metals are melted until they flow together. Also, solder is not a type of glue that holds parts together. In fact, most adhesives are electrical insulators. Simple adhesives cannot make connections that would conduct electricity.



In soldering, only the solder becomes a liquid. It flows over a surface that remains a solid. When the solder cools, it is joined to that surface. Liquid solder actually mixes with the molecules of a metal surface and imbeds itself into every pore. This mixing is called "WETTING". Since no surface is truly smooth, there are always plenty of pores. This gives soldered connections a great amount of physical strength.

The "INTERFACE" area of wetting is where solder has intermixed with molecules of both the wire and the surface. It is this low resistance interface that makes solder a good electrical connection.

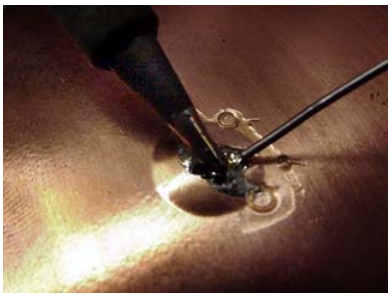
Oxidation and Flux

So far, we've described soldering in ideal conditions. However, in actual conditions, most surfaces pick up dirt, wax, grease, or paint. These barriers can prevent wetting and must be removed by scraping or lightly filing.

Yet, even with all this debris removed, there will still be another barrier to wetting because most metals "OXIDIZE" when exposed to air. For example, if you are soldering copper, there will be a layer of copper oxide at the surface. This oxidation is both a chemical barrier and an electrical insulator. If this oxidation is not removed, wetting will not occur because the solder simply can't reach uncontaminated copper. Therefore, solder will bead up just as water beads on a waxed surface.

Oxidation on copper will prevent the solder from bonding to it. Sometimes rosin core solder isn't enough to clean the surface of the copper.

Adding liquid rosin flux can aid cleaning.



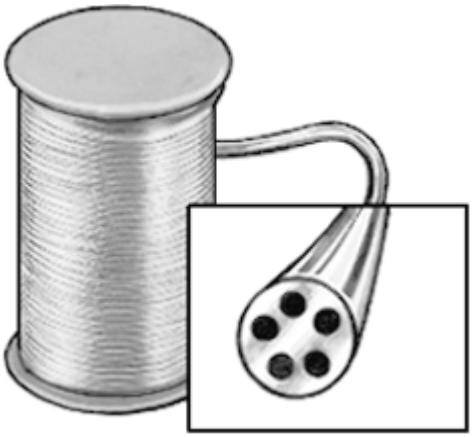
The flux is heat activated opening the pores of the copper plate making bonding much easier.

Fortunately, oxidation can be quickly removed with a substance called “FLUX.” There are two categories of flux available: acid flux and rosin *flux.* Acid flux works well with some kinds of soldering because, when heated, it chemically eats away oxidation. However, it has some serious disadvantages when used on electronic circuits. One disadvantage is that acid flux is still corrosive after a soldered connection has cooled. This corrosion can damage delicate components and circuit boards. Also, acid flux is conductive. Since the flux spreads out wider than the solder, this electrical leakage can cause shorts on a circuit board. Fortunately, most of the problems of acid flux can be solved by using “ROSIN FLUX.”

Liquid Rosin Solder Flux

While it is hot, rosin flux is also corrosive and it chemically removes oxidation. But when the connection cools to room temperature, rosin is no longer corrosive and is not electrically conductive. Therefore, rosin flux left on the connection causes no harm to components or circuit boards. However, you should be careful not to leave rosin flux on switch contacts because this may create an open circuit. Both acid and rosin flux are available in powder, liquid or paste form. But using a separate form of flux is inconvenient because of the extra FLUX step needed to apply flux first, then solder. To solve this problem, the flux is integrated as a core in the solder. Solder is available with a core of either acid or rosin flux but, since acid flux is not acceptable for any kind of electronics work, you should always use “ROSIN CORE SOLDER.” When rosin core solder is heated, the rosin actually melts a split second before the solder, flowing onto the work and removing the oxidation. Then the solder melts and flows onto the cleaned surface.

Single Core, Rosin Core Solder


Multi-Core, Rosin Core Solder

Rosin core solder is available in many configurations and sizes 1/16 inch solder with a single core of rosin is the most common type for general electronics. 1/32 inch solder can be used for delicate, precision work. Remember that solder is also available with an acid core, but don’t use this type for electronics work. Be sure you use 60/40 rosin core solder, either 1/16 or 1/32 inch diameter.

REMEMBER: Use ONLY rosin core solder on electronic and electrical circuits!

What are the Proper Soldering Tools?

The right tools can make any job easier. To choose the right tool for your particular soldering needs, let's first examine the way heat is transferred to the work.

Here's a common soldering iron. This tool uses AC line voltage to produce heat in a coil, which is shielded within the housing. From there, heat is drawn into the tip, the part of the iron that contacts the connection. The heat at the tip should be at least 100° F above the melting point of solder.

When the soldering tip touches the connection, the connection becomes a "HEAT SINK" which draws heat away from the iron. The amount of heat absorbed depends on the:

1. Size of the surface to be soldered.
2. Surface area touched by the iron.
3. Condition of the soldering iron tip.
4. Amount of pressure applied.

The size of iron you need depends on the size of the object you want to solder. This is because the bigger the soldered connection, the more heat it will soak up and the more it will lower the temperature of the tip. If the iron is too small or the connection too large, it's possible to bring the temperature below the melting point of solder. On the other hand, too large an iron may damage heat-sensitive components.

Many hobbyists own soldering guns. These tools are popular because they are versatile, heat quickly, and often have two heat ranges. They can perform a wide variety of jobs, but they also disadvantages which make them unsuitable for constant electronics work:

Soldering guns are best uses for heavy-duty applications. There are many reasons why soldering guns should <u>not</u> be used for electronics work:

1. A soldering gun is much heavier than an iron because it contains a bulky transformer. If you're soldering for hours at a time, a gun can be tiresome.
2. The trigger action of a gun requires a few seconds of heat-up time for each connection. For repetitive soldering, this wait is too long.
3. The tip may be too wide for precision work on circuit boards.
4. The gun shape is clumsy for intricate work.
5. The biggest disadvantage is excessive heat. A soldering gun can easily damage components.

For many reasons, the best soldering tool for electronics is the common soldering iron or station. This tool is sometimes called a "PENCIL IRON" for two reasons: the soldering tip is narrow like a pencil point; also, for best control, you hold this tool just as you would hold a pencil.

A soldering iron is rated by wattage, which is directly related to its operating temperature. A 25- to 35-watt soldering iron develops a tip temperature of 650° F, which is the proper temperature for circuit boards. Some larger irons can produce up to 1000° F, and this temperature can permanently damage semiconductors. Even at 650° F, most components can only tolerate heat for under 10 seconds. So, for 90% of your electronics work, a 25 to 35-watt iron is the right size.

The tip of an iron is usually a copper rod which conducts heat efficiently. This rod is often ironclad and sometimes has a gold, silver, or nickel-plating to prolong tip life and increase heat transfer.

Soldering iron tips are usually removable and they should be replaced when they become pitted or the plating wears away. There are many shapes and sizes available. So, if you will be doing specialized soldering, you may want an iron with an interchangeable tip.

Cleaning the Soldering Iron

As you solder, the iron's tip picks up wax, grease, dirt and burned flux. Additionally, the hot tip simply oxidizes even when it's not in use. Since this debris that collects on the tip is a heat insulator, it makes soldering frustrating and slow. Contaminants on the tip will also flow from the tip into the solder joint making it less reliable. There is a good rule of thumb that will make your soldering easier and quicker:

It's easy to clean the tip of the iron and it will actually save you time in the long run. Just wipe the hot tip on a wet rag or wet sponge.

When a simple sponge and solder won't properly clean the tip, special tip cleaner can restore the iron's tip to new condition.

…Clean the tip every time you reach to use it.

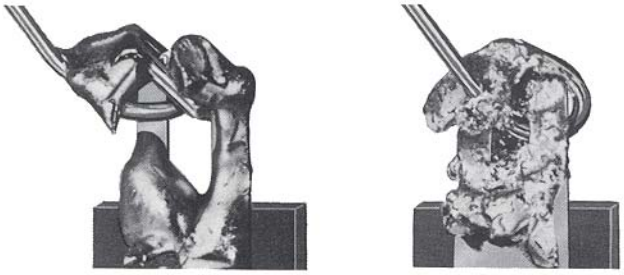
There's another reason for cleaning your iron. Besides picking up dirt, the tip will oxidize as does any other metal surface. This condition is aggravated with a soldering iron because the heat accelerates oxidation and an oxide layer is another heat insulator that can prevent quick, efficient soldering.

To avoid oxidation, "TIN" the tip, as shown here. This is accomplished by cleaning the tip as soon as possible after the iron is hot. Then apply a fresh layer of solder. This solder coats the tip and provides a good barrier against air and dirt.

What is a Bad Solder Joint?

Making a good solder connection is extremely important because, in electronics, a bad connection is almost useless. To help you see the difference between a good and bad connection, let's first examine the causes of a bad one.

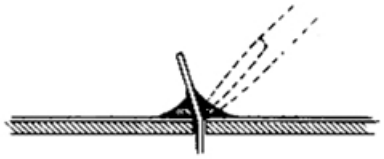
A connection may fail when the iron is too small or the soldered item too large. This is because the solder may seem to melt, but it may only be in the "plastic" temperature range. The solder won't be truly liquid and won't flow or bond properly. The solution is to use a larger iron or leave the iron on the connection longer. But be careful — don't scorch your components by applying too much heat.



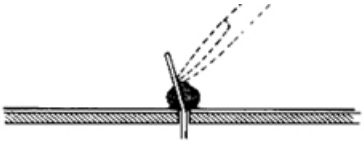
A poor solder joint is often called a "COLD SOLDER JOINT" because the most basic cause is not enough heat.

Cold solder joints also occur because the connected wire is moved while the solder is cooling. The connection must he motionless for several seconds while the solder cools below the "plastic" temperature range. If the solder is disturbed while cooling, it will not properly "mix" with the pores of the soldered surface. But don't try to make the solder cool faster by blowing on it or touching a wet finger to the connection. Solder must harden and cool naturally. Look again at these examples of a cold solder joint. A typical cold solder connection will look dull and gray, grainy, or crystalline. It may break under strain and, most importantly, it may be a poor electrical conductor.

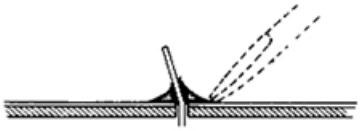
To do its job properly, rosin must first clean oxidation. Then, with adequate heat, it will boil away. If the rosin does not evaporate, it will remain inside the connection and act as an electrical insulator.



In a proper PCB solder connection, heat is applied to both the lead and foil of the PCB at the same time. Solder flows evenly to both lead and pad and forms a "Teepee" shaped well.



This type of PCB rosin joint is due to heat being applied only to the lead. The solder appears to pull inward as it touches the foil on the PCB forming a ball. Rosin residue forms on the PCB preventing electrical connection.



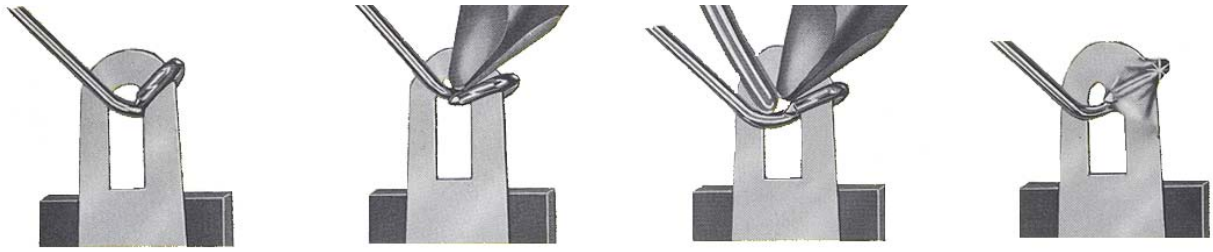
This type of PCB rosin joint is due to heat being applied only to the pad. The solder appears to pull inward as it touches the lead as it exits the PCB. Rosin residue forms on the lead preventing electrical connection.

All the problems caused by a cold solder or rosin joint are serious, since the connection is physically weak and has a high electrical resistance. The connection may even be an intermittently open circuit.

To correct a cold solder joint, reheat the connection and apply a little extra solder. To correct a rosin joint, reheat without adding solder. Watch for a small wisp of smoke to indicate that the rosin has boiled away.

Another kind of bad connection is the "ROSIN JOINT". Too much solder or too little heat causes this mistake.

How To Make A Good Solder Connection



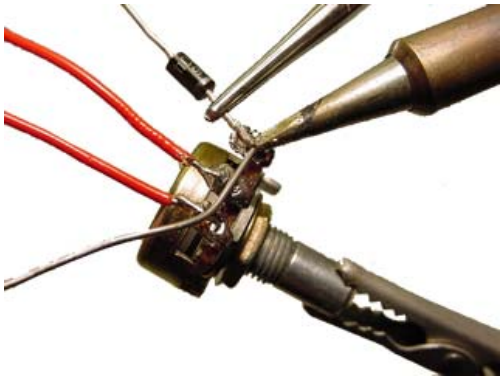
An example of how to make a good solder joint. The connection is smooth, meaning fully liquid solder has flowed evenly over the surface. The connection is also shiny, which is evidence that the connection was not moved while cooling. When a connection looks like this, good "wetting" has occurred.

To solder a good connection, follow these steps...

1. Be sure not to nick the wire if you are stripping wire insulation. Damage to the wire will create a weak spot and the connection can fail no matter how well you have soldered it. Anchor your work so it doesn't move while the solder is cooling. If you're working with a lug terminal, hook the wire lead around the terminal. Bend wires slightly on circuit board connections. If you're soldering components with two or more wire leads leave room for heat expansion. It very important that you make a good physical connection before applying solder.
2. Always clean your iron before applying solder. Wipe the tip clean on a wet rag or sponge.
3. Place the soldering iron tip against both the wire lead and the surface so both reach approximately the same temperature. Heat the connection for 2 to 3 seconds be fore applying solder.
4. Touch the solder to the side of the connection opposite the soldering iron. The heat will be drawn through the work to reach the solder. Let a small amount of solder flow onto the work. Let solder flow only until the connection is covered.
5. Heat the connection only long enough to melt the solder thoroughly. Solder should flow evenly over wire leads and the surface before you remove the iron.
6. Notice that this connection is smooth and shiny, and that the solder blends smoothly with the terminal. Don't use too much solder. The solder should conform to the contours of the joint and not be ball-shaped.
7. Remove excess flux from the joint using a commercial flux cleaner.

There is another kind of soldering known as "TACK" soldering to a flat surface or foil on a circuit board. There is no way to anchor this type of work, but with a steady hand, you should be able to hold the connection so it is not disturbed while cooling.

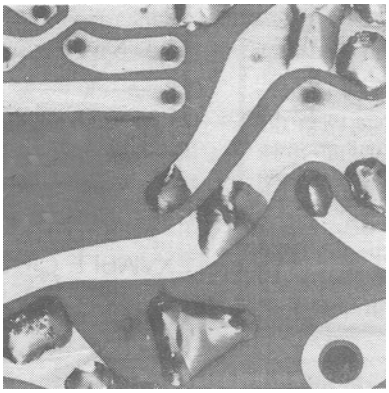
One way to accomplish this is with needle nose pliers, alligator clip, or heat sink clamp. By placing the pliers on the wire lead between the connection and the body of the component, you draw excess heat into the pliers instead of the component. You can also use commercially available “heat sink clamps” for this same purpose.

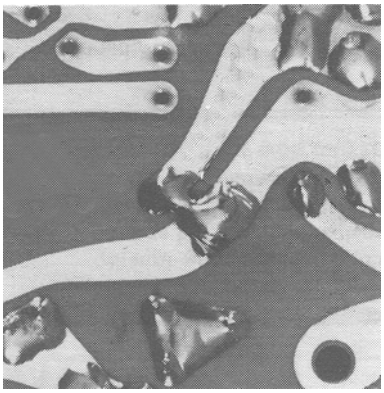


Use a “HEAT SINK” if you’re soldering delicate components. A heat sink will prevent some of the excess heat from reaching the component you are soldering.

One problem is space restriction and the difficulty of soldering among the small components and circuit paths of a circuit board. Therefore, when you’re soldering a circuit board, use a soldering iron with a small tip. Use a thin thread of solder and apply as little solder as possible.

Another problem is heat damage. Because components are so small, they are also heat sensitive. Heat simply has a short distance to travel between the wire lead and the body of a component. Unfortunately, damage to these components often can’t be detected until the board is tested. Also, the adhesive holding the copper foil paths to the circuit board can be burned, which allows the foil to tear away.





The most serious problem with circuit boards can be “Solder Bridging.” Using too wide a soldering tip or too much solder causes this mistake. As a result, solder runs between circuit paths or terminals and creates a short circuit.

Solder bridging is another type of bad solder connection …especially with printed circuit board soldering. If undetected, this mistake can damage many components throughout the board. Fortunately, solder bridging is one circuit board problem that can be repaired easily if detected before power is applied. But this falls under the heading of “Unsoldering and Repairing Circuit Boards”, which will be explained in the next section.

Soldering wave machines, like the one shown here, can automatically solder thousands of connections per minute. But the boards soldered by machine must still be repaired by hand.

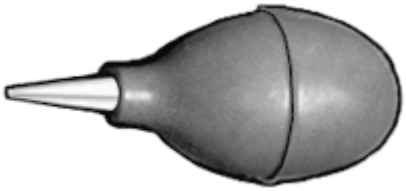
Unsoldering and Repairing Circuit Boards

Circuit board repair may be the most important skill in soldering. To repair circuit boards, the defective components must first be removed. The simplest way to remove a bad component is to melt the solder and pull out the component.

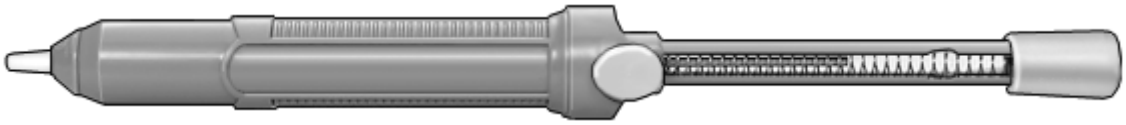
But this method has several disadvantages:

1. Repeated heating and melting of solder can damage components or circuit board foil.
2. Anchored or bent wires leads are difficult to pull from terminals while you are also holding a soldering iron.
3. When the component is removed, the terminal or circuit board hole will still be closed by the remaining solder.

Therefore, the best repair method is to remove the solder completely before you remove the component. There are several tools available to help you do this easily.

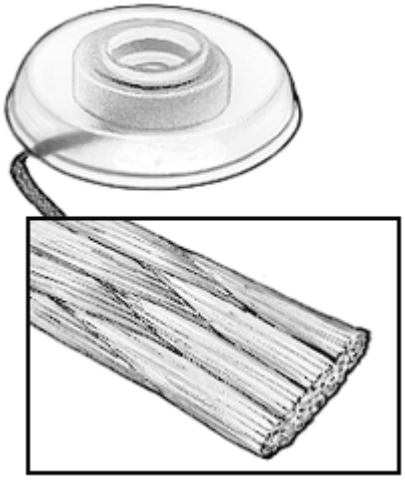


The most common soldering repair tool is the "VACUUM BULB," which has a heat resistant plastic tip. To use this tool, first squeeze the bulb, and then melt the solder. When you release the bulb, it will create a vacuum that sucks the melted solder into the bulb. You may have to repeat the operation before all the solder is removed.



Manipulating both the soldering iron and the vacuum bulb at the same time can be quite a feat. So, the high-vacuum "SPRING LOADED PLUNGER" has been developed. With this convenient tool, you simply compress the spring plunger. When the solder melts, you press a button, which releases the spring. This creates a powerful vacuum and the solder is sucked into the cylinder. Usually, all the solder is removed in one operation.

Many vacuum-type tools are available and one of them may be the best choice for you. However, the cleanest and safest tool is also the simplest. That tool is "BRAIDED FLUX", braided wire coated with non-corrosive rosin flux.



To make the job even simpler, a sophisticated soldering iron has been devised with a vacuum nozzle as part of the soldering tip. This tool makes unsoldering a faster and easier one-hand operation. For industrial uses, there are even power-driven vacuum machines that remove melted solder.

When it is heated, the flux thoroughly cleans the braided wire. There are many small strands in the braid, which break up surface tension so the melted solder from the connection flows into the braid by capillary action. Then you simply cut off and discard the chunks of braid that are filled with solder.

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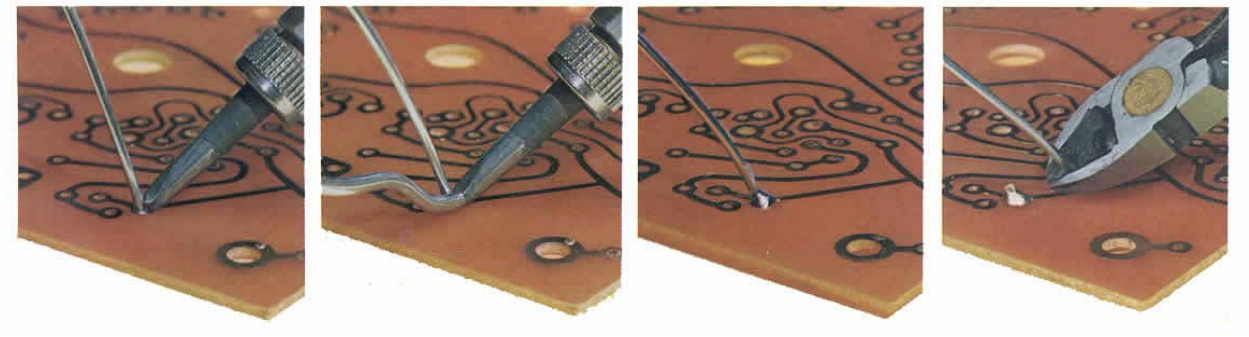
These are several reasons why professionals prefer to remove solder with braided flux:

1. It quickly and effectively removes most of the solder from a connection.
2. It is flexible and, if needed, can fit in tight spots.
3. You can press its end onto the connection with the tip of your soldering iron. For this reason, it is easier to handle than a vacuum bulb.
4. You can also use a combination of vacuum tools and braided flux.

Soldering Printed Circuit Board (PCB) Components

Once you have repaired a circuit board by removing a faulty component, follow these steps to re-solder a functioning component. As always… Clean your iron before applying solder. Wipe the tip on a wet rag or wet sponge.



Step 1. **Step 2.** **Step 3.** **Step 4.**

1. Push the component lead through the hole so the lead comes up on the foil side of the circuit board. Bend the lead slightly so it is anchored and will not move while you are soldering. Place the tip against both the wire lead and the foil so that both reach approximately the same temperature. Heat the connection for about 2 seconds before applying solder. The solder iron should not be in contact with the foil for more than 5 seconds at a time. Otherwise the glue that holds the foil on the circuit board will soften and the foil pattern will lift from the PCB.

2. Touch the solder to the side of the connection opposite the soldering iron. The heat will be drawn through the work to reach the solder.
3. Heat the connect-ion only long enough to melt the solder thoroughly. Let a small amount of solder flow evenly over the wire lead and the foil before you remove the iron. Let solder flow only until the connection is covered and let cool.
4. Clip off the excess lead at the top of the solder well using diagonal cutters.

Surface Mounted Technology (SMT)

One of the greatest advantages of SMT is that Computer Automated Manufacturing (CAM) robots can easily and quickly assemble printed circuit boards.

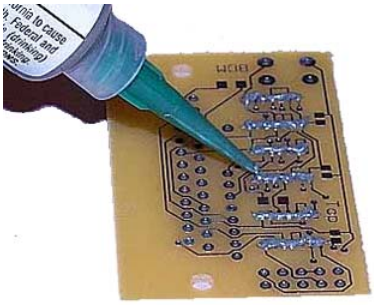
Special equipment like this CAM CO2 laser soldering machine precisely heats up thousands of joints a minute resulting in very highly reliable soldering.

Up until now, we've focused on thru-hole soldering techniques. Thru-hole soldering is a circuit board packaging technique where the component leads and the IC pins on the chips are inserted into holes in the printed circuit board (PCB). The leads and pins are bent on the foil side of the circuit board, snipped off, and then soldered.

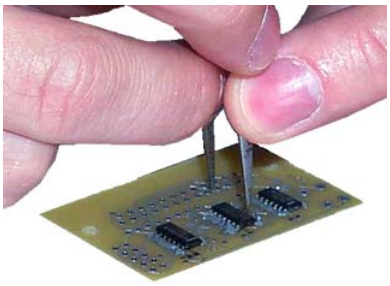
You've probably noticed that the big trend in consumer electronics has been the make things smaller and smaller while increasing their power and ease of use. It's also interesting to note that for decades, the size of electronic devices like calculators, audio equipment, and computers were prevented from getting any smaller due to the leads and pins on the electronic components that are soldered to the device's PCBs. The components were simply too big to make the circuits any smaller. Engineers thought that if the electronic components could be made smaller, then the printed circuit boards could be made smaller, and ultimately the electronic device itself could be made smaller. Their work to remove the component leads would result in a new soldering technique called Surface Mounted Technology or SMT.

SMT is a circuit board packaging technique in which the leads (pins) on the chips and components are soldered on top of the board, not through it. Boards can be smaller and built faster. SMT stands for surface mount technology, and an SMD is a surface mount device.

The process includes soldering but is very different that thru-hole soldering. The basic differences between thru-hole and SMT soldering is that the components are smaller and have no leads and the PCB doesn't have lead holes. Instead of rosin core solder, a water-soluble solder paste is used. Finally, instead of a soldering iron, special equipment like CO2 lasers and CNC hot-air soldering machines are used.

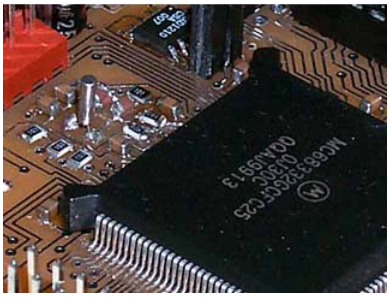


SMT can be done without the expensive specialized equipment. In fact, the entire process can be done quite cheaply using a simple toaster oven. In the first step, you apply strips of solder paste onto an SMT printed circuit board. The PCB has to be clean and it takes a bit of practice to get the right amount of solder past on the SMT solder pads.



Next…You position the devices so their connectors are directly over the pads on the PC. The correct position is essential. After the SMDs are placed on the circuit board, then the entire project is placed in an oven.

4 min.	200 deg.	Warm up board and allow temperatures to equalize.
2 min.	325 deg.	Bring temperature up to saturation.
30 sec+	450 deg.	Temperature raised until solder melts and beads at individual pins, then held for 30 additional seconds.



When the solder past is heated, the solder bridges will disappear, bead up, and adhere to both the SMD and PCB pad. This photograph shows resistors, capacitors, and intergraded circuits… All SMDs.

Special tools and techniques are required to remove, rework, and re-flow SMDs once they've been soldered. Be sure you do it right the first time.

Incidentally… If this portion of the circuit used thru-hole soldering components and techniques, it would be 400% larger.

Above All… Safety

This material gives you the basic steps of soldering with enough background to explain how solder works and why. But the most important thing you can learn is SAFETY.

Molten solder is extremely hot and it can spill or splash like any liquid. A ball of solder could fly from a loose wire into your eyes. You could easily be burned.

Soldering guns and irons are even hotter than the solder. If you handle equipment carelessly, you may injure yourself or someone else. So, to protect your vision, wear safety glasses. And always treat solder and soldering tools with respect. With a bit of caution and practice, you can make soldering a safe and very useful skill.

Practice Makes Perfect

It's good to learn the theories, but you must spend time in hands-on practice to perfect your skills and technique. As soon as you've finished studying this material, you'll apply what you have learned by soldering wires, terminals, components, and printed circuit boards. Remember that soldering is a manual skill that you must practice to become proficient.

Review:

Soldering is the process of bonding together two or more metals by heating them, melting a tin-lead alloy called solder onto them, and letting it harden.' The basic purpose of soldering, in electronics, is to provide a good electrical connection that is strong physically. The solder molecules actually mix with the molecules of the metals being joined, at their surfaces. This surface-area mixing of the two metals is called "wetting."

A solder alloy with a 60-40 tin-lead mixture is used most commonly for electronic work because it has a very low melting point and it solidifies quickly. But before solder will adhere to a metal, the oxide layer must be removed from the metal's surface by a chemical called "flux". For electronic and electrical work, most of the solder has this flux built right into it. And of the several types available, only rosin-core solder can be used. Use 60-40, rosin-core solder for all your electronic and electrical soldering.

The type of soldering iron you use depends on your application. To solder a large wire to a large metal terminal, for example, you would need a large soldering iron. To solder small electronic components to a circuit board, you should use a pencil iron. Soldering irons are rated in terms of "wattage," an electrical characteristic that tells how much power they will consume. Usually, a 25-35 watt pencil iron is a perfect size for circuit boards, and it will handle most other jobs very well too.

A soldering gun can be another useful soldering tool, but you have to know its advantages and its limitations. Its principal advantage is its off-on, instant-heat feature. Its biggest limitation is that its high heat could destroy small components.

To transfer heat effectively from the soldering iron to a wire or connection, always keep the tip clean and "tin" it at regular intervals. If you let any dirt or burned flux collect on it, this will greatly reduce the amount of heat that it can transfer to the connection. To make consistently good connections, you should clean the tip each time you pick up the iron to use it. Tin the tip regularly by thoroughly cleaning it and then coating it with a layer of solder. This will minimize the formation of oxide on the tip.

Actually, soldering is a fairly simple process. With a little bit of practice, you should be able to make consistently good solder connections and complete each one in only 3 or 4 seconds. The soldering process is described here in the following four steps:

1. Wipe the tip of the iron clean.
2. Place the tip against both the lead and the terminal (or foil).
3. Apply the solder, at the other side of the connection, to the junction point of the lead and the terminal (or foil).
4. Leave the tip on the connection only long enough to thoroughly melt the solder.

Basic Soldering

Exercise 1 – Vocabulary and Theory

Name:	
Period:	
Date:	

Exercise Objective:

I hope you've carefully studied the material in the previous section on soldering. If not, you're going to have to review it to answer the following questions. There are also some vocabulary words you'll have to define. You must complete this exercise before attempting the others in this lesson.

Research Resources:

Company	Web Site	Description
Webopedia	http://www.webopedia.com/	Internet technology encyclopedia.
Techweb	http://www.techweb.com/	Internet technology encyclopedia.

Vocabulary: On a separate piece of paper, define the following words using at least two sentences. Be sure your definitions are in a context regarding soldering.

Alloy	Interface	Cold Solder Joint	Rosin Joint
Capillary Action	Flux	Braided Flux	Thru-Hole Soldering
Wetting	Surface Mount Technology (SMT)		

1. The process where solder mixes with molecules of a metal surface is called _____ .
2. Solder is an alloy of _____ and _____ .
3. The melting point of 60/40 solder is _____ .
4. There are two types of flux. _____ flux is NOT acceptable for electronics work because it is electrically conductive. _____ flux is the type that should be used for electronics work.
5. The tip of the iron should be cleaned on a wet _____ or _____ .
6. A clean iron makes soldering faster because it transfers _____ more effectively.
7. Bad solder connections are often called _____ _____ _____ .
8. Another bad connection can result if the rosin is not heated enough to boil away. This mistake is called a _____ _____ .
9. Place the soldering tip against both the _____ and the pad (or terminal) so that both are about the same _____ .
10. If you are soldering delicate or heat sensitive components, use a _____ _____ to protect the device.
11. When you are soldering a circuit board, use an iron with a _____ tip, a _____ thread of solder and use as _____ solder as possible.
12. _____ _____ is a mistake caused by using too large a soldering tip or too much solder.
13. The cleanest and safest unsoldering method for electronics is to use braided wire coated with _____ flux.
14. To reduce the size of consumer electronics, engineers have removed the leads from electronic components making them smaller. This technology is called _____ _____ _____.
15. Technicians require special tools to remove, re-flow, or rework _____ _____ _____.

Revised 11/19/2003
Frank C. Pendzich © 8 July, 2002

Basic Soldering

Exercise 2 – Use & Care of the Soldering Iron

Name:	
Period:	
Date:	

Exercise Objective:
I really hope you're reading this. Soldering irons have caused a lot of unnecessary pain in my laboratories in the past. I have a few scars myself. Burns and blisters are more often due to carelessness than insufficient training. This lesson will explain the safe use and care soldering irons. Read this information carefully so you don't hurt yourself, those around you, or damage equipment or materials.

Discussion of Fundamentals:

Safety
First…**Soldering Irons Get Hot!** I know that sounds like a real no-brainer. However, you can bet that someone in your class will get a painful reminder about just how hot soldering irons actually get. How Hot? Well… At least 374° F. After all, that's the melting point of 60/40 solder. Actually, soldering irons get much hotter and get hot quickly. Temperatures between 500° and 700° are not uncommon for soldering irons and stations used in electronics work. Just so you're clear about safety… That's nearly 4 times hotter than boiling water. If you've ever been scalded by hot water, then you can guess how painful a soldering iron burn can be. For this reason always wear eye protection and never touch the portion of the soldering iron that's below the handle (even if it's off) or you can get seriously burned.

Second…It's important to remember that the soldering iron shouldn't touch anything that isn't a solder joint. Not only do soldering irons burn human flesh, hair, and clothing they will also melt plastic and burn wire insulation and wooden tabletops. Soldering irons are used for soldering ONLY. Do not use them to melt plastic or burn word. This is not only destructive behavior it damages the iron. Because the soldering iron and heating element gets very hot, you must also keep it way from nearby wires or other components while you're soldering. This includes the power cable to the soldering iron itself. You'll even have to be careful when you're storing the iron (if it's still hot) when your work is complete. Please pay attention to these safety concerns. Otherwise, you'll damage yourself, your work, or the equipment you're using.

First Aid
If you are unlucky enough to get burned here's what to do:

- Immediately cool the affected area with cold running water or ice for ten minutes.
- Remove any rings etc. before swelling starts.
- Apply a sterile dressing to protect against infection.
- Do not apply lotions, ointments, or burst any blisters that may form later.
- Seek professional medical advice where necessary.

Care and Use of a Soldering Iron or Station

Caring for a soldering iron or station involves three things. Inspection, Cleaning, and Maintenance of the:

- Base
- Cables
- Handle
- Tip

How to Care for the Soldering Iron or Station

Before you plug in the soldering iron or station, inspect it carefully. Look for burns or melted insulation on the power cord. If you're using a solder station, you also need to inspect the cable connecting the base to the soldering pencil. Careless use of the soldering iron will burn the insulation on these cables and can expose you to dangerous voltages. Don't use an iron that has exposed wires on their electrical cables.

The best way to repair burns to the power cord and pencil cables is to prevent them. Always put the soldering pencil in the holder with the iron is not in use. Also, keep in mind that the heating element and soldering tip are hot seconds after the iron is plugged-in. Keep these parts of the soldering pencil away from any thing that melts… except solder that is.

The plastic soldering iron handle and cables can be cleaned with spray cleaner and a soft towel. If you're using a solder station, the same is true for the base. As with any electrical device, never spray the cleaner directly on the device. Always spray the cleaner on a towel and then use the towel to wipe done the device. Be sure to wipe away any excess cleaner.

How to Care For Soldering Tip

Most modern soldering irons feature an electro-plated that should never be filed or ground. Most manufacturers offer a large range of tips so there should be no need for individual shaping. If there is a need for a specific tip shape it's best to purchase what you need. Although tips are pre-tinned (solder coating) and are ready for use, you should pretin the tip with fresh solder when heating it up the first time. Any oxide covering will then disappear.

Tip life is prolonged when mildly activated rosin fluxes are selected rather than water soluble or no-clean chemistries. When soldering with temperatures over 665 0 F (350 0 C) and after long work pauses (more than 1 hour) the tip should be cleaned and tinned often, otherwise the solder on the tip could oxidize causing un-wettability of the tip. To clean the tip use the original synthetic wet sponges rather than rags or cloths.

When doing rework, special care should be taken for good pretinnng. Usually there are only small amounts of solder used and the tip has to be cleaned often. The tin coating on the tip could disappear rapidly and the tip may become unwettable. To avoid this the tip should be retinned frequently.

Before you turn the iron off, apply a liberal amount of solder to the tip to form a gob. When you turn the iron off the gob of solder will harden. "Gobbing" the tip will protect the soldering surface from oxidation while the iron is not being used.

Research Resources:

Company	Web Site	Description
Inland Crafts	http://www.inlandcraft.com/Uguides/tipcare.htm	Soldering iron tip care.
Metcal	http://www.metcal.com/tips/1.3.2.htm	Soldering iron care.
Coopertools	http://www.coopertools.com/literature/weller/55578.pdf	Solder station care and use.

Required Materials:

Soldering Iron or Station
Spray Cleaner
Soft Towels
60/40 Rosin Core Solder
Soldering Pencil Holder
Sponge

Use and Care of the Soldering Iron

Procedure: Complete the following steps and have your supervisor rate your work as reliable or unreliable. You must correct any steps that your supervisor has deemed unreliable. Refer to this lesson and the Basic Soldering Technical Manual to perform each of these steps.

Step	√	Description	Supervisor Check	
Make sure the soldering iron unplugged. Wear your eye protection.				
1.		Inspect the power cable to the soldering iron for burned insulation and exposed wires. If you are using a soldering station, also inspect the cable leading from the base to the soldering pencil. Report defects to your supervisor.	**YES**	**NO**
2.		Use spray cleaner and a towel to clean the soldering iron handle and power cord. If you are using a soldering station, also clean the base and cable leading from the base to the soldering pencil.	**YES**	**NO**
3.		Setup the soldering iron or station on a heat resistant work surface. Make sure the soldering pencil is placed in a holder. All cables should be organized for ease of use and your work area should be cleared and ready for soldering.	**YES**	**NO**
4.		Soak the sponge in water and then wring it out so it's damp.	**YES**	**NO**
5.		Plug in the soldering iron or station and turn it on. If it has a thermostat, turn it up to maximum. Let the soldering iron warm up for 5 minutes.	**YES**	**NO**
6.		Brush the tip of the iron on a damp sponge to clean off the oxidation.	**YES**	**NO**
7.		Apply a liberal amount of solder to the tip and then brush it off again. Repeat until the iron tip is clean and shiny. *	**YES**	**NO**
8.		Gob the tip, turn the soldering iron or station off, and put it away. Be sure the cables don't touch against the heating element or tip with the equipment is put away.	**YES**	**NO**
9.		Clean your work area, put away your tools and materials, and throw away your trash.	**YES**	**NO**

* If the tip cannot be cleaned after five or six tries at tinning the tip, then you may need to use a special tip-cleaning compound to get rid of the unwanted oxidation.

Conclusions:

Using equipment with care keeps you and others safe. Taking care of equipment makes it last longer and work reliably when you need to use it. If you take care of your equipment it will take care of you.

Basic Soldering

Exercise 3 – Preparing Wires for Soldering

Name:	
Period:	
Date:	

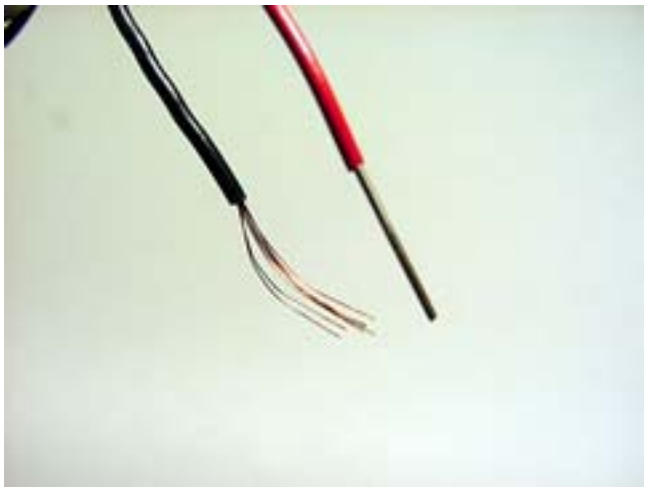
Exercise Objective:

In this exercise, you will learn about the types of wires used in electronics and how to prepare them or soldering. You'll learn how to cut, strip, and tin wires. You'll also learn how to splice stranded wire to solid hookup wire to make the 9-volt battery snap easier to use with your electronics kit.

Discussion of Fundamentals:

There are two types of wire commonly used in electronics. Solid hookup wire and stranded wire are both insulated and come in a variety of gauges. The smaller the gauge, the larger the wire's diameter, and the more electrons the wire can deliver to the load.

Solid hookup and stranded wire are both made of copper. The difference is that solid hookup wire is comprised of one conductor covered with any color of insulator you can imagine. Whereas stranded wire is made of multiple conductors, twisted together, and then covered with an insulator. Solid hookup wire is pre-tinned while stranded wire usually isn't.



Stranded and Solid Hookup Wire

When you use stranded wire, always tin the bare end of each wire by tightly twisting together the separate strands, and then melting a small amount of solder on the wire end to hold the strands together. Use just enough solder to hold the strands together. If you use too much heat, solder will wick up the wire under the insulation. If you use too much solder, the wire end will be hard to bend. (If this happens, reheat the wire end and ten tap it sharply against your work surface to remove the excess solder.) Once the stranded wire is tinned, it can be bent and shaped without the end of the wire fraying.

Research Resources:

Company	Web Site	Description
Univ. of PA	http://www.ee.upenn.edu/rca/funstuff/soldering/soldering.html	Soldering Tutorial
Irrational.org	http://www.irational.org/sic/radio/solder.html	Soldering Tutorial
ETI Electronics	http://www.epemag.wimborne.co.uk/solderfaq.htm	Basic Soldering

Required Materials:

Soldering Iron or Station	60/40 Rosin Core Solder	Soldering Pencil Holder
Sponge (Damp)	Toolkit	4" of 22 or 20 Gauge Solid Hookup Wire
12" of 22 or 20 Gauge Stranded Hookup Wire		9-Volt Battery Snap

Preparing Wires for Soldering

Procedure: Complete the following steps and have your supervisor rate your work as reliable or unreliable. You must correct any steps that your supervisor has deemed unreliable. Refer to this lesson and the Basic Soldering Technical Manual to perform each of these steps. Setup your soldering iron and turn it on. Collect the required materials and clear off a workspace on a heat resistant surface. Wear your eye protection at all times. Remember to keep the tip of the iron tinned at all times.

Step	√	Description
1.		Cut the 12" stranded hookup wire in half using a pair of diagonal cutters.
2.		Use a pair of wire strippers to remove ¼" of insulation from the ends of both stranded wires.
3.		Twist the strands tightly together and tin the ends of both stranded wires.

9-Volt Battery Snap Project

Setup your soldering iron and turn it on. Collect the required materials and clear off a workspace on a heat resistant surface. Wear your eye protection at all times. Remember to keep the tip of the iron tinned

Step	√	Description
1.		Trim the ends of the 9-volt battery snap wires so they are even.
2.		Remove ½" of insulation from the ends of the battery snap wires and tin them.
3.		Remove 1" of insulation from both ends of the solid hookup wire.
4.		Wrap the stranded wire end around the solid hookup wire and solder together.
5.		Repeat the last step for the other stranded and solid hookup wire.
6.		Cut off the excess solid hookup wire for both solder connections.
7.		Cut the solid hookup wire so there is a ½" of wire below the connection.
8.		Repeat the last step for the other stranded and solid hookup wire.
9.		Cut off the excess stranded wire from both connections.

You now have a 9-volt battery snap that will easily plug into the solderless circuit board for your electronics experiments.

Quality Assurance Rubric - Preparing Wires for Soldering Desired Characteristics		Supervisor Check	
1.	**Work Area Preparation** – Is the soldering station setup on a heat resistant work surface? Are the required materials available? Is the solder tip clean/pre-tinned? Eye Protection?	YES	NO
2.	**Wire Preparation** – Is the stranded hookup wire cut into 2 each, 6-inch lengths?	YES	NO
3.	**Wire Preparation** – Is the solid hookup wire cut into a single 4-inch length?	YES	NO
4.	**Wire Preparation** – Have the stranded wires been stripped of ½" of insulation from both ends?	YES	NO
5.	**Wire Preparation** – Has the solid wire been stripped of 1" of insulation from both ends?	YES	NO
	Wire Preparation – Are the stripped ends of all wires free of nicks or scratches? Are all strands available at the ends of the stranded hookup wires?	YES	NO
6.	**Wire Tinning** – Are the bare ends of the stranded wires completely tinned up to and not past the insulation line?	YES	NO
7.	**Wire Tinning** – Is the tinning smooth and shiny? Can you see the twists in the strands of the wire below the solder surface?	YES	NO
8.	**Solder Joint** – Is the solder joint smooth and shiny? Can you see the twists of the stranded wire around the solid hookup wire in the joint?	YES	NO
9.	**Solder Joint** – Are the wires in the solder joint cut to the right specifications?	YES	NO
10.	**Solder Joint** – Is the solder joint physically strong?	YES	NO
11.	**Solder Joint** - Is the insulation on the wires free of burns or melted spots? Is the wire insulation near the joint free of burns or melted spots?	YES	NO
12.	**Solder Joint** – Has solid hookup wire been soldered to both ends of the battery snap?	YES	NO
13.	**Cleanup** – Are all tools, materials, and supplies properly stored. Is the work area clear and clean?	YES	NO
Any "NO" rating has to be corrected before preceding to the next exercise.			

Conclusions:

Preparing wires for soldering is an important step in making reliable solder connections. Stranded wires need to be tinned before they can be soldered to terminals or printed circuit boards. In this exercise you prepared wires and spliced them together to make the 9-Volt battery snap work better with the solderless circuit board.

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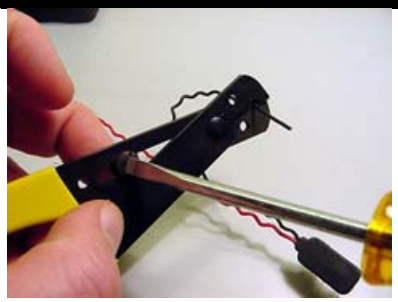
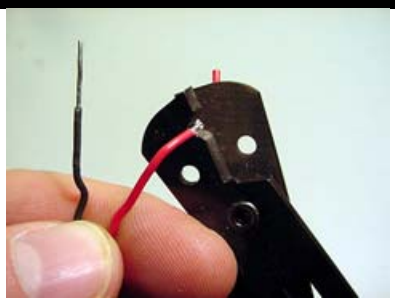
9-Volt Battery Snap Project
Step-By-Step Pictorial

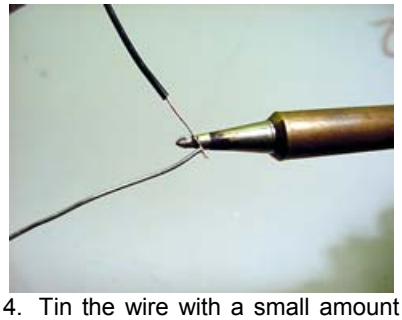


1. Adjust the wire stripper so it strips off the insulation but doesn't nick the wire



2. Strip ½" of insulation from the ends of each wire.

3. Twist the strands tightly together.

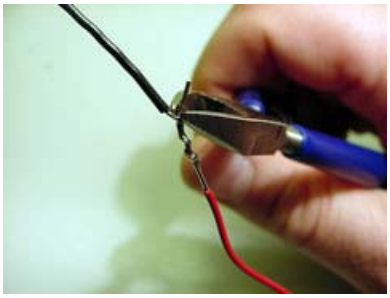


4. Tin the wire with a small amount of solder.

5. The solder should completely cover the exposed wires. You should see the strands below the surface of the solder.

6. Wrap the stranded wire around the solid hookup wire as shown.

7. Solder the wires together. Add just enough solder to do the job.



8. Clip off the excess solid hookup wire.

9. Examine the solder joint to make sure that the solder is smooth and shiny. The solder should conform to the twisted wires.

10. Clip of the solid hookup wire ½" from the solder joint.

11. Here's the completed splice. Do the same with the other battery snap lead.

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Basic Soldering

Exercise 4 – Desoldering

Name:	
Period:	
Date:	

Exercise Objective:
In this exercise, you will learn how to remove solder from solder lugs and terminals. You'll learn how to use solder wick or braided flux and a soldering iron draw the solder out of a solder joint. You'll use these techniques to remove wires from a potentiometer.

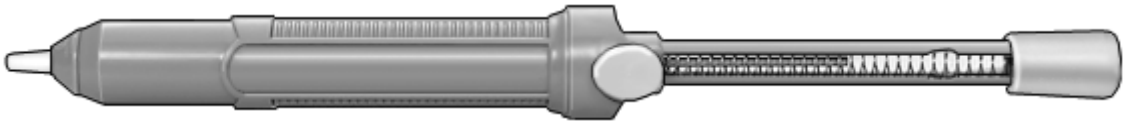
Discussion of Fundamentals:
Circuit board and electronic circuit repair may be the most important skill in soldering. To repair circuit boards, the defective components must first be removed. The simplest way to remove a bad component is to melt the solder and pull out the component.

But this method has several disadvantages:

1. Repeated heating and melting of solder can damage components or circuit board foil.
2. Anchored or bent wires leads are difficult to pull from terminals while you are also holding a soldering iron.
3. When the component is removed, the terminal or circuit board hole will still be closed by the remaining solder.
4. Pulling the wires can fling molten solder from the joint burning you or others nearby.

Therefore, the best repair method is to remove the solder completely before you remove the component. There are several tools available to help you do this easily.

The most common soldering repair tool is the "VACUUM BULB," which has a heat resistant plastic tip. To use this tool, first squeeze the bulb, and then melt the solder. When you release the bulb, it will create a vacuum that sucks the melted solder into the bulb. You may have to repeat the operation before all the solder is removed.



Manipulating both the soldering iron and the vacuum bulb at the same time can be quite a feat. So, the high-vacuum "SPRING LOADED PLUNGER" has been developed. With this convenient tool, you simply compress the spring plunger. When the solder melts, you press a button, which releases the spring. This creates a powerful vacuum and the solder is sucked into the cylinder. Usually, all the solder is removed in one operation.

Many vacuum-type tools are available and one of them may be the best choice for you. However, the cleanest and safest tool is also the simplest. That tool is "BRAIDED FLUX", braided wire coated with non-corrosive rosin flux.

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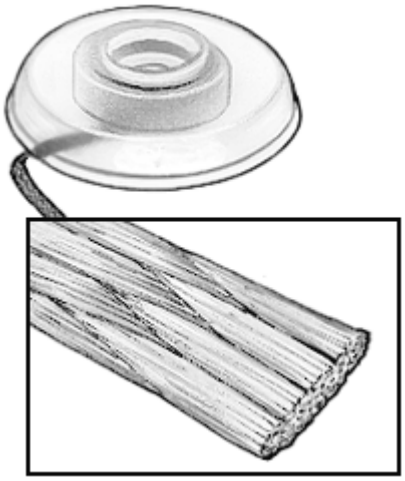


When it is heated, the flux thoroughly cleans the braided wire. There are many small strands in the braid, which break up surface tension so the melted solder from the connection flows into the braid by capillary action. Then you simply cut off and discard the chunks of braid that are filled with solder.

To make the job even simpler, a sophisticated soldering iron has been devised with a vacuum nozzle as part of the soldering tip. This tool makes unsoldering a faster and easier one-hand operation. For industrial uses, there are even power-driven vacuum machines that remove melted solder.

These are several reasons why professionals prefer to remove solder with braided flux:

1. It quickly and effectively removes most of the solder from a connection.
2. It is flexible and, if needed, can fit in tight spots.
3. You can press its end onto the connection with the tip of your soldering iron. For this reason, it is easier to handle than a vacuum bulb.

You can also use a combination of vacuum tools and braided flux.

There will be lots of times while you're soldering and desoldering components that you'll wish you had a third hand. That's what this useful tool is called… a third hand. This one features a magnifying glass for close up work.

The third hand holds small pieces securely while you solder or desolder.

Research Resources:

Company	Web Site	Description
Univ. of PA	http://www.ee.upenn.edu/rca/funstuff/soldering/soldering.html	Soldering Tutorial
Irrational.org	http://www.irational.org/sic/radio/solder.html	Soldering Tutorial
ETI Electronics	http://www.epemag.wimborne.co.uk/solderfaq.htm	Basic Soldering

Required Materials:

Soldering Iron or Station
Soldering Pencil Holder
Sponge (Damp)
Toolkit
Potentiometer or Other Terminal Device With Wires Soldered to the Terminals
Solder Wick or Braided Flux

Desoldering

Procedure: Complete the following steps and have your supervisor rate your work as reliable or unreliable. You must correct any steps that your supervisor has deemed unreliable. Refer to this lesson and the Basic Soldering Technical Manual to perform each of these steps. Setup your soldering iron and turn it on. Collect the required materials and clear off a workspace on a heat resistant surface. Wear your eye protection at all times. Remember to keep the tip of the iron tinned at all times.

Step	√	Description
1.		Secure the device you're trying to desolder in a bench vice, 3rd hand, or on your work surface so you can apply a fair amount of pressure the to solder lugs with a soldering iron.
2.		Unwrap about 4" of solder wick from the spool. Position a clean piece of braided flux directly over the lug you wish to desolder.
3.		Press the tip of the soldering iron over the braided flux pushing through to the solder lug.
4.		Continue pressing until the solder melts and gets drawn into the braided flux. Do not hold the soldering iron against the joint for more than 5 seconds at a time. Otherwise you damage the component.
5.		Repeat this procedure for the remaining solder lugs on the device.
6.		Once the solder is removed, use a needle nose pliers to peel away the wires that were soldered to the terminals. You may have to use a pair of diagonal cutters to cut the wire away. Applying a little heat with the soldering iron may be enough to break the wire free to remove it.

Quality Assurance Rubric - Desoldering Wires from Terminals Desired Characteristics		Supervisor Check	
1.	**Work Area Preparation** – Is the soldering station setup on a heat resistant work surface? Are the required materials available? Is the solder tip clean/pre-tinned? Eye Protection?	YES	NO
2.	**Desoldering** – Has enough solder been removed from the terminals to allow reinstallation of wires?	YES	NO
3.	**Desoldering** – Are the terminals still intact and in good shape.	YES	NO
4.	**Cleanup** – Are all tools, materials, and supplies properly stored. Is the work area clear and clean?	YES	NO
Any "NO" rating has to be corrected before preceding to the next exercise.			

Conclusions:

Desoldering is a necessary repair technique. To replace defective components, you first have to remove it and the best way to remove a component is to remove all the solder that's holding it in place. The best and least expensive way to remove unwanted solder is using solder wick or braided flux. This technique can be used for desoldering both terminals and printed circuit board solder joints.

Desoldering Wires from Solder Lugs
Step-By-Step Pictorial

Secure the device you're trying to desolder in a bench vice, 3rd hand, or on your work surface so you can apply a fair amount of pressure the to solder lugs with a soldering iron. Unwrap about 4" of solder wick from the spool. Position a clean piece of braided flux directly over the lug you wish to desolder. Press the tip of the soldering iron over the braided flux pushing through to the solder lug. Continue pressing until the solder melts and gets drawn into the braided flux. Do not hold the soldering iron against the joint for more than 5 seconds at a time. Otherwise you damage the component.

Repeat this procedure for the remaining solder lugs on the device.

Once the solder is removed, use a needle nose pliers to peel away the wires that were soldered to the terminals. You may have to use a pair of diagonal cutters to cut the wire away. Applying a little heat with the soldering iron may be enough to break the wire free to remove it.

Basic Soldering

Exercise 5 – Soldering Wires To Terminals

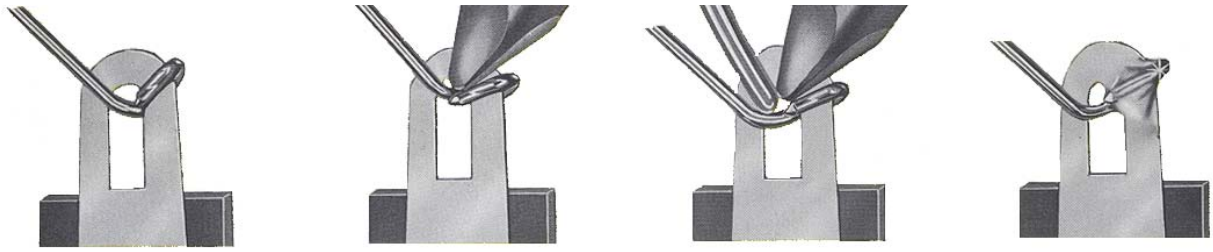
Name:	
Period:	
Date:	

Exercise Objective:

In this exercise, you will learn how to solder wires to solder terminals and lugs. You'll learn how to solid hookup wire to the lugs commonly found on potentiometers and switched. The intent is help you prepare components that you'll use for the electronics experiments.

Discussion of Fundamentals:

How To Make A Good Solder Connection to Terminals



An example of how to make a good solder joint. The connection is smooth, meaning fully liquid solder has flowed evenly over the surface. The connection is also shiny, which is evidence that the connection was not moved while cooling. When a connection looks like this, good "wetting" has occurred.

To solder a good connection, follow these steps...

1. Be sure not to nick the wire if you are stripping wire insulation. Damage to the wire will create a weak spot and the connection can fail no matter how well you have soldered it. Anchor your work so it doesn't move while the solder is cooling. If you're working with a lug terminal, hook the wire lead around the terminal. Bend wires slightly on circuit board connections. If you're soldering components with two or more wire leads leave room for heat expansion. It very important that you make a good physical connection before applying solder.
2. Always clean your iron before applying solder. Wipe the tip clean on a wet rag or sponge.
3. Place the soldering iron tip against both the wire lead and the surface so both reach approximately the same temperature. Heat the connection for 2 to 3 seconds be fore applying solder.
4. Touch the solder to the side of the connection opposite the soldering iron. The heat will be drawn through the work to reach the solder. Let a small amount of solder flow onto the work. Let solder flow only until the connection is covered.
5. Heat the connection only long enough to melt the solder thoroughly. Solder should flow evenly over wire leads and the surface before you remove the iron.
6. Notice that this connection is smooth and shiny, and that the solder blends smoothly with the terminal. Don't use too much solder. The solder should conform to the contours of the joint and not be ball-shaped.
7. Remove excess flux from the joint using a commercial flux cleaner.

Research Resources:

Company	Web Site	Description
Univ. of PA	http://www.ee.upenn.edu/rca/funstuff/soldering/soldering.html	Soldering Tutorial
Irrational.org	http://www.irational.org/sic/radio/solder.html	Soldering Tutorial
ETI Electronics	http://www.epemag.wimborne.co.uk/solderfaq.htm	Basic Soldering

Required Materials:

Soldering Iron or Station
Soldering Pencil Holder
Sponge (Damp)
Toolkit
12 Inches of Solid Hookup Wire
Solder Wick or Braided Flux
Potentiometer or Other Terminal Device With Wires Soldered to the Terminals

Soldering Wires to Terminals

Procedure: Complete the following steps and have your supervisor rate your work as reliable or unreliable. You must correct any steps that your supervisor has deemed unreliable. Refer to this lesson and the Basic Soldering Technical Manual to perform each of these steps. Setup your soldering iron and turn it on. Collect the required materials and clear off a workspace on a heat resistant surface. Wear your eye protection at all times. Remember to keep the tip of the iron tinned at all times.

Step	√	Description
1.		Secure the device you're trying to solder in a bench vice, 3rd hand, or on your work surface.
2.		Cut the solid hookup wire into 3 each, 4" lengths.
3.		Strip ¼" of insulation off both ends of each wire.
4.		Use a needle nose pliers to bend one end of each wire into a "J" shaped hook.
5.		Insert the hooked end into the hole of each terminal on the device and crimp it to make a good physical connection.
6.		Apply heat to both the wire and terminal to a solder lug and add some solder to complete the solder joint. Add just enough solder to close the hole of the terminal. Hold the connection still until the solder hardens.
7.		Cut off any excess lead length from the solid hookup wire.
8.		Repeat this process for each terminal on the device.

Quality Assurance Rubric - Soldering Wires to Terminals Desired Characteristics		Supervisor Check	
1.	**Work Area Preparation** – Is the soldering station setup on a heat resistant work surface? Are the required materials available? Is the solder tip clean/pre-tinned? Eye Protection?	YES	NO
2.	**Soldering** – Does the solder flow completely around the joint? Is there just enough solder to do the job?	YES	NO
3.	**Soldering** – Does the solder joint look smooth and shiny?	YES	NO
4.	**Soldering** – Is the insulation on the wires free of burns and melted spots?	YES	NO
5.	**Soldering** – Is the end of the wire's insulation within one wire's diameter from the terminal?	YES	NO
6.	**Soldering** – Are the ends of the wires properly hooked and stripped.	YES	NO
7.	**Cleanup** – Are all tools, materials, and supplies properly stored. Is the work area clear and clean?	YES	NO
Any "NO" rating has to be corrected before preceding to the next exercise.			

Conclusions:

When soldering… It's really all about transferring heat. There're a few things you have to pay close attention to make sure there's a good transfer of heat during soldering. First… There has to be a good physical connection between the things you're trying to solder together. That's why you have to hook and then crimp the wires to the terminals. A good physical connection allows both the wire and terminal to reach high temperatures at the same time. Second… Heat up both the wire and the terminal by touching them both at the same time. Use about the same amount of pressure as if you were writing with a pencil. Applying solder a second or two after you've applied heat will allow the solder to flow through the joint. The joint should look smooth and shiny and contain only enough solder to do the job. There should be only a small space between the end of the insulation and the terminal… about the diameter of the wire itself.

Soldering Wires To Solder Lugs
Step-By-Step Pictorial

Secure the device you're trying to solder in a bench vice, 3rd hand, or on your work surface. Cut the solid hookup wire into 3 each, 4" lengths. Strip ¼" of insulation off both ends of each wire.

Use a needle nose pliers to bend one end of each wire into a "J" shaped hook.

Insert the hooked end into the hole of each terminal on the device…

…and crimp it to make a good physical connection.

Apply heat to both the wire and terminal to a solder lug and add some solder to complete the solder joint. Add just enough solder to close the hole of the terminal. Hold the connection still until the solder hardens. Cut off any excess lead length from the solid hookup wire.

Here's an example of three bad solder connections. The first one… not enough solder. The middle one… Too much heat has burned the insulation. The end one… Two much insulation was stripped off.

Here's another example of poorly soldered terminal connections. The one on the left has too much solder while the one on the right shows signs of the wire being moved while the solder was still in the plastic state. It's not smooth or shiny. The insulation on the wire is also melted indicating too much heat.

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