General instructions on soldering printed circuit boards (PCB) and testing and debugging your circuit

Your Photonics kits contain 4 PCBs and sets of electronic components. Each component needs to be soldered in the correct space on the PCB. Some components (such as the LED, photo-transistor, voltage regulator etc) are polarized and need to be connected into the circuit in a very precise manner.

(a) **What is Solder?**

Solder is an alloy (mixture of metals) that melts at relatively low temperature and, when it cools and solidifies, forms an electrical contact with the metal surfaces of the PCB and component leads by mechanical interlocking with surface irregularities. This process is called "wetting" and is important for both good electrical contact and good mechanical strength of the bond.

Metal oxides on the metal surfaces prevent thorough wetting, hence "flux" is incorporated in the solder. This is made of resin (in electronics solder) that (at high temperature) release acids which dissolve any oxide layer.

(b) **Preparation**

The face of the soldering iron tip should be coated with a thin layer of solder. "Tinning" the soldering iron tip is achieved by heating it to solder melting temperature and then applying a small amount of solder. Excess may be removed with a damp sponge. Tinning facilitates efficient heat transfer from the tip to the component.

N.B. Tips should be cleaned regularly during use with a moist sponge pad. Take care not to remove the molten solder coating.

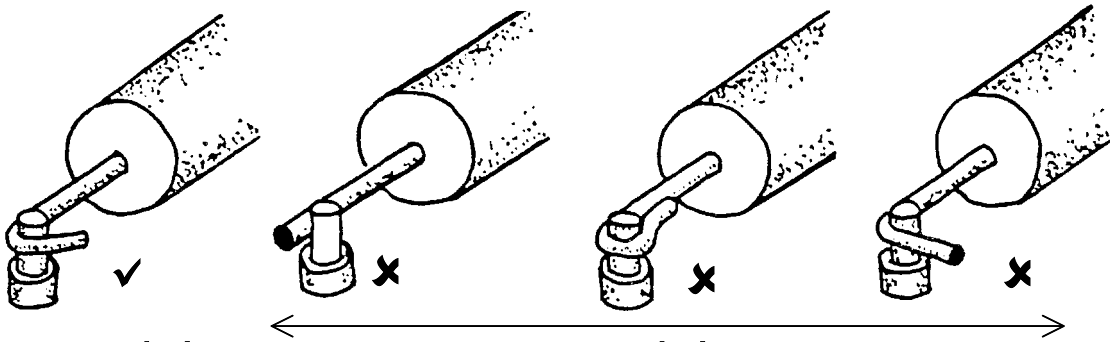
(c) **Preparing components**

1. If a lead is tarnished (oxidized), clean it with sandpaper or steel-wool thus enabling a good electrical contact.
2. If printed circuit board tracks are tarnished, they may be cleaned with an abrasive powder cleanser (or by light sanding) and then washed in water and dried.
3. Leads should be tinned by heating and applying a little solder before connection, thus preventing oxidation and ensuring even heat transfer to the lead.
4. Multi-strand hookup wire is prepared by stripping back approximately 7 mm of insulation and twisting the strands together. The hot iron is applied for approximately 1 second, along with a small amount of solder. This not only coats the wire but also makes for easy manipulation when joining.

(d) **Mounting Components on Terminals**

1. Cut component leads to required length making sure to leave enough for bending and some slack.
2. Bend lead around pin to an angle of around 135° (as shown in the first diagram in Figure 1. Any more will make de-soldering and removal of the component difficult and any less will make the joint over-reliant on the mechanical bond the solder provides.

N.B.~ If. the pin has an eyelet, thread the lead through and bend to no more than 90°



Correct Method Incorrect methods

Figure 1

3. When several leads are terminated together, each should be connected separately facilitating easy removal. Under no circumstances twist leads together.

4. Where possible use insulated wire to connect terminals thereby lessening the prospect of shorts.

(e) **Mounting Components on Circuit Boards:**

1. Mount all components from the non-copper side unless otherwise specified.

2. Solder in those components which have the ***lowest profile*** (vertical height) ***first***, then solder in those components which stick out further.

3. Insert leads through holes and splay them (bend them slightly away from each other) as shown in figure 2 so as to hold components in place for convenient soldering.

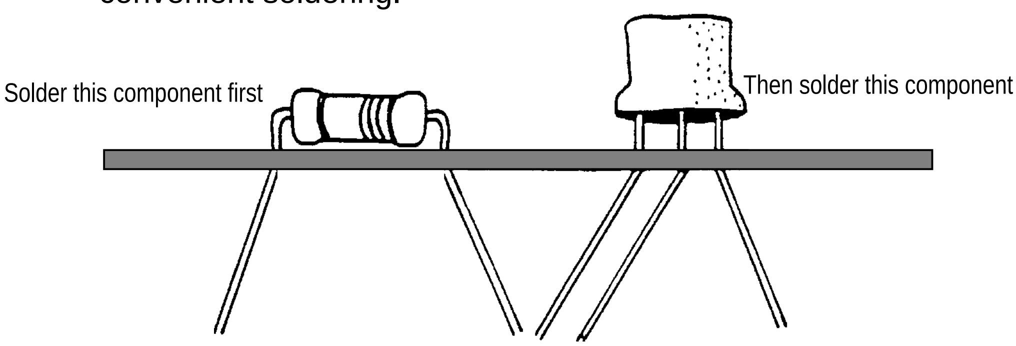


Figure 2

N.B. Boards held in clamps rather than on the workbench make for stable soldering conditions and lessen the probability of damaging components.

(f) **Soldering**

To get a good connection between a component part and the PCB copper surface (this is often coated with a layer of solder and has a shiney "silver appearance), you need to follow the following steps:

1. Turn on the iron and allow it to reach correct operating temperature.
2. Solder on the side opposite the component (ie the copper side). You need to heat the component part *and* the copper surface of the PCB (these two are called the "joint") at the same time.
3. Apply the soldering iron tip to the part of the joint with the *greatest* mass for a few seconds. This will maximize heat transfer, thereby allowing efficient soldering. Heating any smaller part will require a longer time to bring the joint up to molten solder temperature, thereby increasing the risk of component damage.
4. Maintaining the heat, apply a little solder to the joint (not to the soldering iron tip). If the joint is clean, solder should flow freely, wetting the area properly and making a smooth shiny connection.

- A bad joint (i.e. not smooth and continuous) will require reheating or even de-soldering. Such a joint may be the result of tarnish (oxidation) and will result on a bad mechanical and electrical connection.
- Take care not to move parts during soldering or solidification. This can result in a "dry" joint i.e. a poor electrical connection.
- After soldering of all joints is completed, cut off the excess leads. Leave enough lead so if you make a mistake you can unsolder and then re-solder the component. After final testing of the circuit, cut off the excess leads so the copper side of the PCB is reasonably flat.
- Note that if insufficient heat is applied, the solder may solidify before wetting occurs giving a bad contact. Also the flu may not be activated and the joint may eventually tarnish (again giving a bad contact). In this case, the mechanical joint will be weak and the "dry" solder joint can sometimes be pulled apart.

A good solder joint will be covered by a uniform area of solder that meets the parts of the joint at a shallow angle as shown in figure 3. The solder should be smooth and bright in colour.

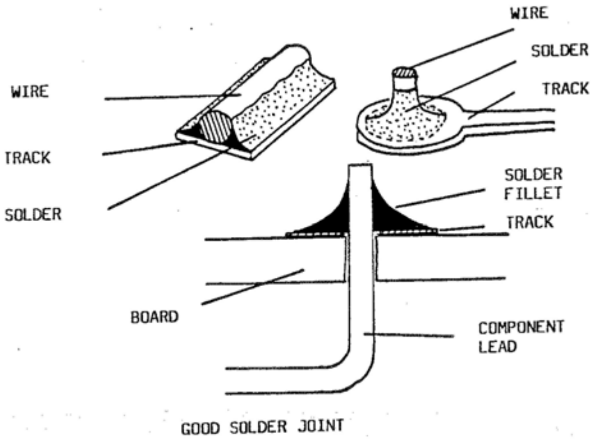


Figure 3

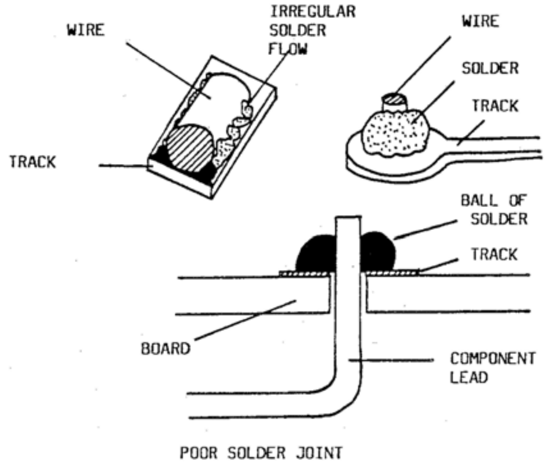


Figure 4

With a bad solder joint, the solder meets the parts of the joint at an abrupt angle as shown in figure 4. The solder flows irregularly and may appear dull.

(g) **De-soldering**

De-soldering can be accomplished by one of two techniques…

1. Using de-soldering "wick" (a woven braid of copper strands).

   Apply the de-soldering wick to the joint and heat, applying pressure to create a good contact. The molten solder will then flow into the fluxed braids. Once the solder has been removed from the Joint, the used wick should be cut-off and disposed of. The components can then be easily parted from the PCB.

2. Using a solder-sucker (a device that uses a spring-loaded piston)

   Gently heat the joint to be removed with the soldering iron, then quickly apply the solder-sucker nozzle to the joint. Releasing the spring-loaded plunger results in molten solder being drawn into the barrel (via a suction effect). Depressing the plunger will automatically clear the barrel of re-solidified solder. This process may have to be repeated several times before a joint is clear of solder and can be parted.

(h) **Testing and Debugging**

When construction of the circuit is complete, it must be tested, and if it doesn't work properly the faults must be rectified. This process is known as debugging. The testing stage may also involve some adjusting of components (usually potentiometers or variable resistors) to get the output to respond by some known amount to a given change in the input.

Testing the circuit is simple enough. Before the circuit is connected to a power supply and powered up, you should examine the board carefully. Make sure all components are in the right place and that all polarized components (like the LED, voltage regulator, photo-transistor, tantalum capacitors etc.) are connected the correct way around. Now make sure the circuit is correctly connected to the power supply and that the circuit is provided with the required inputs (if any). Its operation can then be observed. The output is checked against what would be expected. However, probably your circuit will not work the first time you power it up. This is when debugging is required. Use the following guide to help you get your circuit working.

1) Connect power supply and earth lines to the appropriate terminals of a laboratory power supply or battery. If using a laboratory power supply, set the output to zero or the minimum voltage and turn on the power. Slowly increase the voltage to the required value. At this stage, some catastrophic failure may occur if a component has been soldered in

incorrectly (e g. diode in the wrong way). Look for signs of disaster:- plumes of smoke from a component, often accompanied by a distinct smell. Or a component may just become very hot to the touch and start to look a rather burnt brown (or If severe, black). A distinct bang or pop may also be heard. Be watchful for any of these disaster indicators as you are increasing the power to the circuit. Turn off power immediately anything bad is suspected. Try to locate the dead or dying component(s).

2) If the circuit seems O.K., proceed to check its operation. You will either find it works satisfactorily, or has a fault that fits into one of three broad categories-

(a) Doesn't seem to work at all
Output is not what is expected and just sits at one meaningless value.
(b) Partially working.
Output changes, but does not behave as expected. This could mean that the circuit simply needs calibrating, but the problem could be more serious
(c) Intermittent fault.
Circuit alternates between working normally and displaying a fault of type (a) or (b). This is usually the hardest type of fault to correct.

3) Inspect copper-side of PCB for poor solder joints, solder bridges (incorrect solder flows between adjacent joints) and gaps or shorts in or between copper tracks.

Poor solder joints often look dull (should be shiny) or bead like (should be continuous and smooth) and make little or no contact to the conductor pad or lead. Because such a "dry joint" often makes or breaks contact in response to a knock or vibration, it is often the cause of an intermittent fault.

Solder bridges are tiny slivers of solder that can wrongly connect two nearby soldered joints. They are caused by the soldering iron touching two different joints at once, or slipping quickly from one joint to another.

Gaps in copper tracks may be very thin (hair thin) and are to see. A magnifying glass is often helpful. Sometimes using a multimeter to check conductivity along the track is the only way to find them.

Shorts (a short-circuit) between copper tracks can also be thin and hard to see. Again a magnifying glass and multimeter might be useful.

Also check the component side of the board for unwanted shorts between component leads. Sometimes the leads of adjacent components manage to touch if they are left too long.

4) Fiddle with adjustable components (usually potentiometers) if the output is unchanging or incorrect. Often the output remains fixed at a particular value if one of the potentiometers is set to an extreme of its range. If this is the only thing that appears to be the problem, proceed to calibrate the output.

5) Check power supply and ground lines (called rails) for correct voltages and polarities. If any voltages are found to be incorrect (and cannot be adjusted to their correct values using calibration potentiometers if present) try isolating different components and/or circuit sections while measuring the rail voltage to see what is causing the voltage to remain incorrect.

6) Check test point voltages if any are given in the circuit description. Again try adjusting potentiometers if present, or try isolating components before and after the test point.

7) Check that components are inserted correctly, and not reversed (back to front) or with leads incorrectly placed.

8) Check that the components are what they should be (including correct resistor values). You will need to read resistor colour codes, and check the manufacturers codes for other components. Remove any suspicious components and measure their values or test their operation accurately. **IMPORTANT**: In general, components cannot be tested accurately while still soldered in place.

9) Trace through the circuit using a multimeter or oscilloscope. Generally an oscilloscope is better, because you can see whether the correct wave-forms are present. Use the meter to accurately measure voltages where necessary. To properly trace the circuit operation you need to understand what each component is doing. You must check that the voltage present after a particular stage is what you expect given the input to that stage.

There is no guarantee that you will be able to find what is wrong with your circuit. Debugging electronic circuits successfully is very much a skill that only comes with experience. As a result the process can be very time consuming. To give yourself the best chance of getting your circuit working, be thorough during the construction stage, double checking that components are inserted correctly and that tracks are making the appropriate connections. If a fault does present itself, measure as much related information (test point voltages, power supply rails etc.) as you can to assist you in tracking down the problem.