Soldering Guide

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There essentially three ways to solder components onto a printed circuit board:

1. **Hand soldering using a traditional soldering iron** – there are plenty of these in the lab from classic Weller soldering pencils to slightly fancier temperature-controlled stations with easily changed tips. Make sure the soldering iron has cooled before you try to change the tip!

    a. This is classic stuff, and the best way to go for through-hole components, components on perf-board, and other medium to large scale components. Use a tip that's large enough to heat the connections through and look for nice shiny solder joints with smooth profiles.
    b. You can also solder surface-mount technology (SMT) components using a standard soldering iron and traditional roll-solder. It helps to use tweezers to hold the components, and also to put a bump of solder on one of the pads first before securing one end of the SMT component. This works well for passive components in 1208, 0805, and even 0603 if you're careful.
    c. You can solder SMT IC packages with fine-pitch pins (down to 0.5mm pitch) using the "drag soldering" technique. Tack down (with solder) the IC on the corners. Use a "hoof" tip on the soldering iron and start with a small bead of solder in the hoof (you probably need less solder than you think you do for this!). Then place and drag the hoof across the pins for a nice clean solder connection. See the videos linked to the course Canvas page for more details.

2. **Hot-air soldering with a hot-air soldering station** – we have one of these in the lab. It's basically a hand-held heat gun with a highly directed stream of hot air that gets up to soldering temperature.

    a. The hot air technique works best with solder paste rather than roll solder. Solder paste is a mixture of solder and flux and melts/solders at a lower temperature than roll-solder. Place the paste carefully on the pads before placing the component, then use the hot air to melt the solder paste. It helps to hold down the component with tweezers or a pointed probe so it doesn't blow away. Also, keep the hot air moving so it doesn't heat up the components too much in one place.

3. **Reflow soldering in the reflow oven** – This is the fastest way to solder a whole PCB in one shot, but it does take some preparation. It's also really only for SMT components. It's not really practical to do reflow soldering of through-hole components. In an industrial setting through-hole components are "wave soldered" rather than "reflow soldered" and we don't have anything resembling a wave-soldering setup.

   Basically, you put solder paste on the solder pads on the PCB, place the components so they're nestled into the solder paste, then "cook" the whole thing in the reflow oven so that everything gets soldered all at once.

   The procedure is as follows (and at all steps, the inspection scope is very handy for checking how things are looking!):

   a. Clean your PCB with isopropyl alcohol.
   b. Apply solder paste to the solder pads. You should be careful, but you don't need to be obsessive here. The solder mask on the PCB will repel the liquified solder so it will not stick (much) to the non-pad areas. But, if you put too much solder paste on the pads, especially for IC packages, you risk forming bridges that you'll have to fix later (by drag-soldering or hot-air rework).
      i. If you want to, you can get a solder stencil from the same company that you used to fabricate your PCB. This is a metal stencil with holes matching the solder pads on the PCB. You can then use a bead of solder paste and a paint scraper to "squeegee" the solder through the stencil onto the board in one pass. This is how industrial boards are pasted (in stencil machines, but still…)
   c. Place the components on the board – nestle them into the solder paste which is sticky enough to hold them down. Again, be careful, but you don't need to be obsessive. The surface tension of the liquified solder paste will pull the components into position. Tweezers are essential here.
   d. Turn the oven on and make sure the reflow profile is set on the oven. This may take some experimentation on your part to get right for your particular solder paste. More on this later… Assume for now that it's set.
   e. Place the board on the solder drawer in the oven.
   f. Press "Run" on the oven, and watch to make sure that the temperatures are looking correct for your solder paste profile.
   g. Wait for the "Cool" cycle to complete – but the board will still be very hot – between 70-100°C. It will burn you if you're not careful!
   h. Open the drawer and carefully remove the (still hot) board – tweezers or needle-nose pliers are useful here. Let the board continue to cool before inspecting
   i. Inspect the board using the inspection scope and use the hand soldering irons or hot air to fix anything that looks like it needs fixing.

Setting the Reflow Oven Soldering Profile

The reflow oven goes through five phases while "cooking" the board and achieving the soldering of the SMP components onto the PCB.

1. **Pre-heat** – in this phase the board is raised to a temperature high enough to vaporize and drive off moisture on the board – typically 100-150°C. Hold for 1-2 minutes.
2. **Heating** – In this phase the board is raised to a temperature high enough to start activating the flux in the solder paste. This will help distribute the flux onto the solder pads to make a better soldered connection – typically around 170-200°C depending on the solder paste formula, and for around 1-2 minutes.
3. **Soldering** – In this phase the board is raised to a high enough temperature to liquify the solder and make the soldered connection. This again depends on the solder paste formula with leaded solder typically using a lower temperature than lead-free solder. This should be *at least* 25°C above the melting point of the solder.
    a. For leaded solder this is typically is around 230-240°C
    b. For lead-free solder this is typically a bit higher – perhaps 240-270°C
    c. Linger at this temperature for around 30sec.
4. **Keep/Preservation** – In this phase the temperature is slowly lowered from the soldering temperature so that the solder hardens nicely without crystalizing or cracking.
    a. The target temp for leaded solder tends to be around 200°C
    b. The target temp for lead-free solder tends to be around 240-250°C
5. **Cooling** – In this phase the oven fan comes on to help cool down the now-soldered board. The target temperature for cooling tends to be around 150°C. Note that this is still hot enough to burn! But, it's cooled enough that you can now open the oven and retrieve your board (carefully!).

Unfortunately, there is no one set of times and temperatures that work for all solder pastes. You'll need to check the specs on the paste that you're using to set the temperatures and times for the oven's reflow schedule. Remember that solder paste doesn't last forever (typically they have a listed lifetime of 6-9 months, but I've used older paste successfully), and it lasts longer if you keep it in a refrigerator when you're not using it. But, let it come up to room temperature before using for best results.

Equally unfortunately, our oven doesn't work like you might think it does. When you set a temperature and time for one of the phases listed above, it does NOT wait until it hits the temperature set-point, and then start counting down. Instead, it uses the set-point as a target/limit, and the time as how long it will take to try to each that temperature.

That is, if you want the heating phase to hit 180°C and then linger for 1min, you need to know how long it will take the oven to reach 180, and factor that in to the time! This seems odd to me, but that's apparently the way our oven works… So, some experimentation is required! It's OK to run cycles on the oven with nothing in it just to see how long it takes to get to certain temperatures.

Finally, and still unfortunately, the oven takes a while to heat up, especially to higher soldering temperatures. The "Solder" phase is limited to 1min 30sec by the oven software, and sometimes you'll need to use all 1:30 just to get up to temperature. So, you may want to use the "Keep" phase at the soldering temperature just to make sure you have enough time at the high soldering temperature. Again, some experimentation for your paste formula may be required.

I'm including some tables here of some standard solder paste formulas and suggested timing. Use them as a starting point, but again, you may need to adjust.

For just one example, using Sn63-PB37 soldering paste, I used the following settings successfully (your mileage may vary):

1. Preheat - 140°C for 2min
2. Heat - 175°C for 2min
3. Solder - 235°C for 1:15
4. Keep - 200°C
5. Cool - 150°C

Soldering temp/time phase parameters for various different solder alloys:

Solder Type	proportion	Warm-up (℃/1min)	Heating (℃/1min)	Soldering ℃/30s	Preservation ℃	Cooling ℃
Low-temperature ,leaded	Sn43-Pb43-Bi14	100-120	130-150	200-210	170	150
Lead-free low temperature	Sn42-Bi58	100-120	120-130	180-200	150	150
Lead-free low temperature	Sn48-In52	100-120	120-130	180-200	150	150
Lead, mid- temperature	Sn63-Pb37	130-150	170-180	230-240	180	150
Lead, mid- temperature	Sn60-Pb40	130-150	170-180	230-240	180	150
Lead, mid- temperature	Sn62-Pb46-Ag2	130-150	170-180	230-240	180	150
ıot ıd-free, mid- temperature	Sn96.5-Ag3.5	130-150	180-190	240-250	240	150
Lead-free, mid-temperature	Sn87-Ag3-Cu3-In7	130-150	180-190	240-250	240	150
Lead-free, mid-temperature	Sn91-Zn9	130-150	180-190	240-250	230	150
Lead-free mid-temperature	Sn95.4-Ag3. 1-Cn1.5	130-150	180-190	250-260	240	150
Lead-free mid-temperature	Sn99.3-Cu0.7	130-150	180-190	270-280	260	150
Lead-free high temperature	Sn94-Ag3-Cu3	130-150	190-220	240-250	240	150
Lead-free high temperature	Sn97-Cu3	130-150	190-220	270-280	250	150
Lead-free high temperature	Sn95-Sd5	130-150	190-220	270-280	250	150

Physical characteristics for common solder alloys. Remember that you should use a soldering temperature of at least 25°C above the alloy's melting point.

Solder alloy									Melting temperature	Mechanical properties			conductivity
Sn	Pb	Ag	Sb	Bi	In	Au	Cu	Zn	Liquidus (℃)	Push Strength (MPa)	Elongation (%)	rigidity (HB)	
63	37								183	61	45	16.6	11.0
60	40								183	60	45	16.6	11.0
10	90								299	41	45	12.7	8.2
5	95								312	30	46	12.0	7.8
62	36	2							179	64	39	16.5	11.3
1	97.5	2.5							309	31	50	9.5	7.2
96.5		3.5							221	45	55	13	13.4
	97.5	2.5							304	30	52	9.0	8.8
95			5						245	40	38	13.3	11.9
43	43			14					163	55	57	14	8.0
42				58					138	77	20-30	19.3	5.0
48					52				117	11	83	5	11.7
	15	5			80				157	17	58	5	13.0
20						80			280	28	-	118	75
	96.5					3.5			221	20	73	40	14.0
87		3			7		3		221	45	60	14	9.0
91								9	199				
95.4		3.1					1.5		217				
99.3							0.7		227				
95			5						240				

Here's another table of common solder alloy characteristics. Remember that you should use a soldering temperature of *at least* 25°C above the alloy's melting point.

Alloy	Melting temperature
Sn63 Pb37	183 °C
Sn62 Pb36 Ag2	179 °C
Sn96.5 Ag3 Cu0.5 (SAC305)	217-219 °C
Sn96 Ag4	221 °C
Sn92.5 Ag3.5 Cu1 Bi3	213 °C
Sn42 Bi58	138 °C

For soldering with lead, the Sn63Pb37 alloy is almost universally used. For lead-free soldering, the alloy Sn96.5Ag3Cu0.5 is the most common. The alloy is also known as the abbreviation SAC305.