

Soldering

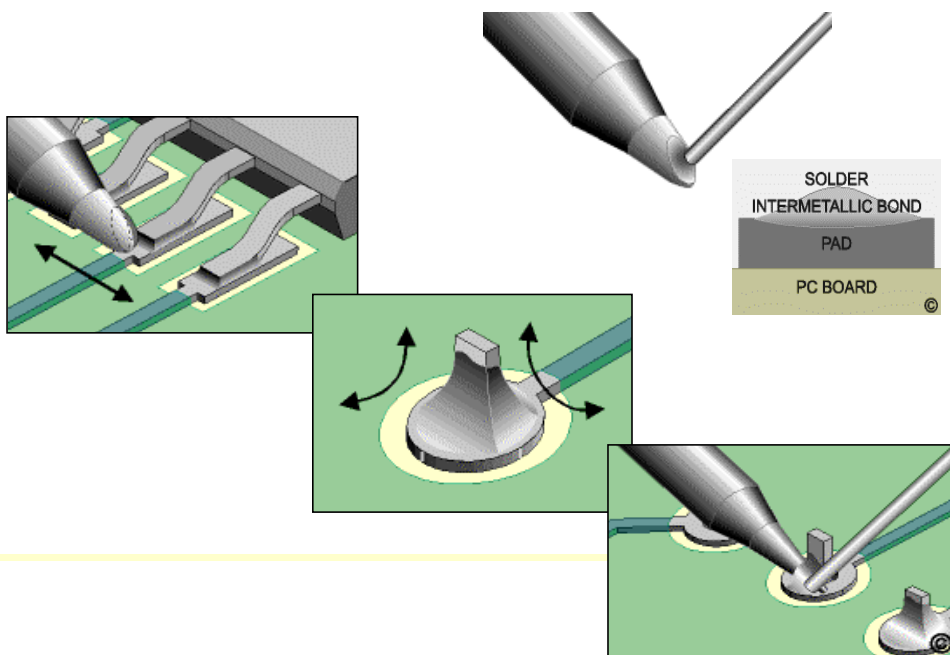


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SOLDERING

Theoretical background for technicians

1. Introduction :

Progress within the electronics industry would not have resulted in the mass production of electronic appliances as we know them today, without a similar progress in the field of soldering technology.

To be able to understand how soldering techniques are used in the electronics industry, we first have to get familiar with the materials used during the soldering process, and we have to learn how a soldering connection is created on a molecular level.

Soldering is an old technique for creating permanent electrical and mechanical connections between metals. In contrast to ordinary glueing, which makes only a physical connection between materials (although electrically conducting glue also exists) soldering causes a chemical reaction with other materials, creating a new alloy.

There are several soldering techniques, which all have a few things in common: basic metals, soldering flux, solder and heating.

2. Basic metals :

When we place electronic components on a PCB, the legs of the components and the soldering lands on the PCB, are the basic metals that will connect with the solder.

Several metals like copper, bronze, silver and some types of steel react with solder and make a strong chemical and physical connection.

Other materials like aluminium, titanium, etc. are difficult or even impossible to solder.

The fact that materials exist which can not be soldered is very important, as these materials can be used for making soldering machines and soldering irons. These materials can also be used for covering components during soldering.

There is a direct relationship between how strongly the surface of the basic metal oxidizes and how the soldering reacts on this: When there is more oxidation present, the soldering connection will be weaker.

The fact that most metals oxidize very quickly when heated, is a specific problem, because if one wants to obtain a chemical soldering reaction, a high temperature is necessary...

Flux is used to counteract this oxidation problem.

3. Soldering flux :

Although the soldering surface looks clean, there is always a thin layer of oxide on the metals. This layer always arises as soon as the metal is exposed to air. Reliable soldering connections can only be made on "clean" surfaces. "Clean" surfaces could be accomplished using cleaning product, but this would be insufficient as metal oxidizes incredibly fast when heated. To prevent the creation of the layer of oxide, the use of soldering flux is necessary.

Using soldering flux on the basic metals before the soldering starts has various reasons and advantages:

The main reason of the use of flux is to stop the oxidation of the basic metals during heating. The flux makes sure that the air can't reach the soldering surface, and therefore prevents the formation of oxidation during warming up.

Most of the different flux types have acid components which are used to remove the oxidation that is already present on the basic metal.

If a very strong acid is active in the flux, theoretically it would be possible to remove all the oxides. This however is in practice not possible, as the acid would also affect the PCB and the components, which of course is not the intention.

Therefore there will always be a search for the balance between a flux that contains strong acids, and as a consequence also removes the oxides more effectively (but also affects the PCB), and a flux that contains a less strong acid and therefore removes less oxides. (but does not affect the PCB).

Most fluxes though use types of acid. Therefore it generally is necessary to remove the flux residues after soldering.

When solder is applied, the flux needs to flow off so that the solder can make direct contact with the basic metal. During this process it is however impossible to avoid the flux mixing with the solder.

Flux developers make use of this fact to develop a flux that has the property to reduce the surface tension of the solder on contact, as a result of which better "wetting" arises.

Flux consists of natural or synthetic resin and chemical additives, called activators.

In PEM a "no clean" flux of Tamura is used (for the placement of Flat-Package-IC's). Consequently it is not necessary to remove the flux after soldering.

Furthermore it is not necessary to add extra flux when doing easy manual soldering because the soldering wire contains flux (3.3 %), like a resin core.

4. Solder :

There several existing metals and metal alloys that can be used for soldering.

The choice for using a certain metal is based on the properties of the metal:

Is the metal flexible or fragile? How well does it conduct heat?

Does it expand rapidly when heated? What is the electrical resistance of the metal?

How strong is it? Is it toxic? And not unimportant: what does it cost?

Although it is not perfect, an alloy of tin and lead is most often used traditionally.

Pure tin melts at 203°C and pure lead melts at 330°C. A mixture of both metals has a lower melting point.

By using a different mixture the melting temperature of the soldering alloy can be changed.

A alloy of tin and lead (e.g. 60/40) has a relatively low melting point (183°C) and can be produced at a relatively low price, in comparison to other alloys with similar properties.

Lead is a very cheap and can be found in a lot of places. Therefore the cost of the tin-lead alloy is mainly determined by the cost of tin.

When this alloy is warmed up, it goes through several phases:

the alloy goes from a "fixed" condition, to a "paste" condition (semi-liquid), and finally becomes totally liquid. It is difficult to solder with an alloy that is in a "paste" condition: because there is little movement or vibration during this "paste" condition, this can cause bad soldering.

If the alloy is of 50% tin and 50 % lead, it starts to melt at a temperature of 193°C, and will be totally melted at a temperature of 216°C.

To prevent bad soldering during the "paste" condition, "eutectical" solder is used.

An "eutectical" alloy is an alloy that, when heated, goes immediately from a fixed condition to a liquid condition: the "paste" stage is effectively skipped.

An "eutectical" tin-lead alloy contains 63% tin and 37% lead.

Often a tin-lead alloy with 60% tin and 40% lead is used. This alloy can be produced cheaper than the eutectical solder because it contains less tin. But because this alloy is almost "eutectical", it can effectively be used for soldering.

During soldering, be careful to make no sudden movements whilst the solder is cooling.

This can cause "interrupted connections" and therefore unreliable soldering.

An "interrupted" soldering connection has a rough and irregular surface and appears dim instead of clear and shiny.

It is also very important that no impurities get into the solder.

If small metal particles from the components get into the soldering "cup" of the soldering machine.

This can result in a serious change to surface tension, and consequently bad soldering connections.

These metal impurities could even change the melting temperature of the solder.

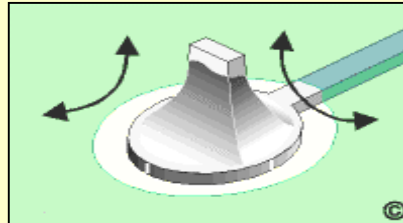
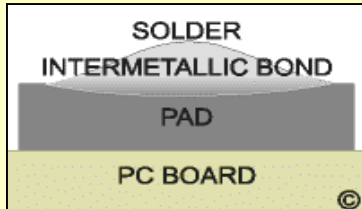
5. Heat, generation of soldering connection

If the solder gets in contact with a copper surface, the solder dissolves and penetrates the copper layer.

The molecules of the solder and the copper get mixed and a new alloy is created, consisting partially of copper and partially of solder.

This reaction is called "wetting" and has as a result an "inter-metallic" connection

between the components. "Wetting" can only take place if the surface of the copper does not contain oxides. The solder and the surface of the copper also have to be at the right temperature before the "wetting" can take place.



6. Soldering with a soldering iron:

The following 4 factors determine the quality of the soldering connection:

- clean surfaces
- temperature
- time
- quantity of solder

a) Clean surfaces:

"dirt is the enemy of a good soldering connection!"

It is enormously important that there are no impurities on all of the components (including the soldering bit). Soldering on "dirty" components is not possible!

Old PCB's or components sometimes can not be soldered due to a large layer of oxide on the islands and the legs of the components.

In such cases the solder is rejected and goes to everywhere, except for where we want it to go.

In a desperate attempt to solder in such a situation, a common reaction is to raise the soldering temperature. However, this is certainly not a solution. On the contrary!

The only correct solution is thorough cleaning. (e.g. with a brush of glass fibre)

Before the soldering iron can be used, the soldering bit first has to be coated with tin.

Some solder has to be melted onto the bit. Afterwards the bit has to be cleaned.

For cleaning the soldering bit, it is best to use a slightly moistened sponge (with demineralized water). The use of ordinary tap water is not recommended, because the silver layer on the bit gets affected by calcium in the tap water, which results in less thermal contact. This diminished thermal contact runs the risk of cold soldering, etc.

To improve the thermal contact between the bit and the soldering surface, it is advisable to coat the soldering bit with a little bit of solder before every soldering action.

b) Temperature & time :

The temperature of the soldering bit is not the most determining factor for successful soldering:

the heating cycle (combination of temperature of the bit and the time the heating takes) is!

How fast the soldering components warm up, how warm they get and how long they stay warm, are the most important factors that have to be controlled to make a reliable soldering connection.

The time soldering takes is very important. A soldering task may only take a couple of seconds: when heated too long, the components and the soldering lands can be damaged.

It is also totally wrong to use the soldering bit to rub melted solder across the soldering surface.

Although the temperature of the bit is not the most determining factor, it is advisable to do soldering at the lowest possible temperature.

The first that has to be examined before the soldering starts is the "thermal mass" of the components.

Every soldering task has its own specific "thermal mass" which is determined by the heat absorption of the components. For soldering e.g. the component pins and solder lands.

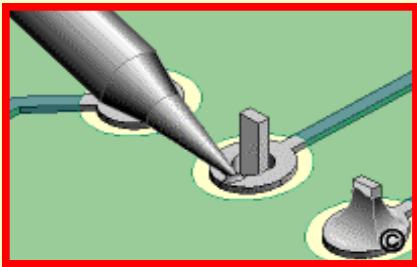
For components on a heat sink there will be a large thermal mass. In other words: the heat will be "absorbed" by the heat sink, as a result of which more warmth will have to be added than e.g. for soldering the leg of an IC.

Secondly it is very important that the temperature of all the components that will be soldered have more or less the same temperature.

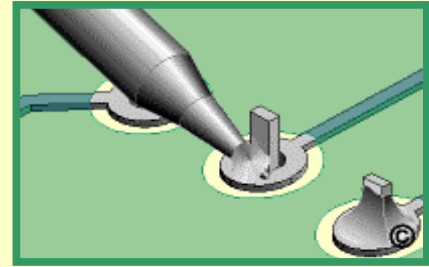
An example: it is necessary that the leg and the soldering land have had at the same time the necessary warming up before the solder is added.

We have to take care that, while warming up, the soldering bit gets in contact with both the leg and the soldering land.

"Thermal contact" is therefore very important.



*The thermal contact is low
The warmth is transmitted by means of the bit
to the leg and the soldering land*



*The thermal contact is higher
by adding a bit of solder
to the point of contact*

The size and the shape of the soldering bit, as well as the position of the bit, will determine whether or not it makes a good thermal contact. For being able to make a good thermal contact in all circumstances, different types of soldering bits exist (different shapes).

Normally the soldering bit has to be placed on the "largest mass point" of the soldering connector that needs to be made.

This will make fast heating possible.

c) Adding solder & quantity

The last factor necessary for a high quality soldering connection, is adding the correct quantity of solder.

Too much solder is an unnecessary waste and can aid the formation of "bridges" across legs

If not enough solder is added, this can cause an "insufficient soldering" or "dry soldering"

Adding the correct quantity of solder takes a lot of exercise and experience

Melted solder always flows from a "colder" area to a "warmer" area.

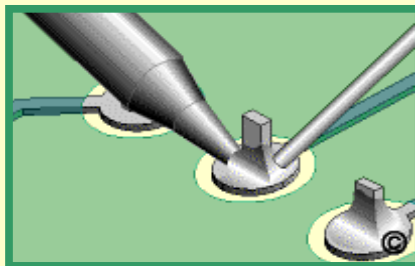
Before the solder is added, the surface temperature of the components to be soldered has to be higher than the melting temperature of the solder.

Never let the soldering wire melt by holding it against the soldering bit. This may cause the solder to fall on a surface where the temperature is lower than the melting temperature

This can result in a cold soldering, with almost no or insufficient "wetting".

If the solder is added to a clean, fluxed and sufficiently heated surface, then the solder will melt and flow nicely without direct contact with the heat source. (soldering bit)

Therefore it is advisable to put the soldering wire on the sufficiently heated surface so that the solder melts as a consequence of the contact with the heated surface



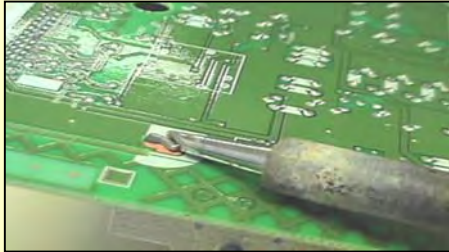
*The solder is melted as a consequence of the contact with
the heated surface. No contact with the soldering bit is necessary.*

d) Soldering : 7 steps



1. Cleaning of the soldering bit:

For soldering to be effective, the soldering bit has to be clean: no dirt and no oxides are allowed on the soldering bit. The soldering bit needs to be cleaned before soldering.



2. Heating of the components that will be soldered.

For soldering to be effective, the components which have to be connected, have to be heated (in this case the pin and the solder lands) to a temperature that at least equals the temperature of the melting point of the soldering alloy. (183 °C)

Bear in mind the "thermal mass", the type of bit and the position of the bit!



3. Adding the solder:

After both components are heated sufficiently, solder can be added.

Let the solder melt as a consequence of the contact with the heated surface. In other words: don't make any direct contact with the soldering bit.



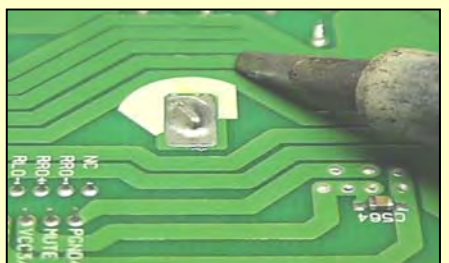
4. Quantity of the solder to be added and letting the solder flow.

Let the solder flow nicely between both components and add solder until the right quantity is reached.



5. Remove the soldering wire

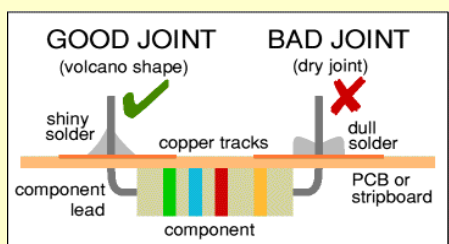
When sufficient solder is added, the soldering wire may be removed.



6. Remove the soldering bit.

When the solder has nicely flowed open, and there is "wetting", the soldering bit may be removed so that the solder can solidify.

Pay attention for possible sudden movements during this operation. (risk of "disturbed" soldering)



7. Check the soldering connection

Check the soldering connection.

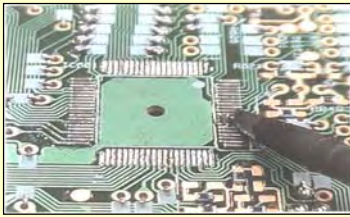
Nicely formed soldering is shining and even. Also pay attention to the shape: a spherical shape is not good!



e) Soldering of a flatpackage IC

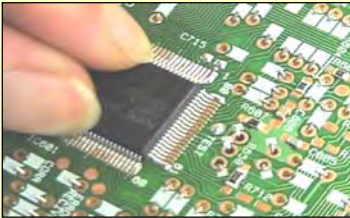
For soldering a "Flat-package IC" (gull wing type) one can use, beside the ordinary point soldering (= leg by leg), a special soldering technique: the DRAGGING TECHNIQUE.

For this technique, one must use a special soldering bit that will, after filling-up, act as a kind of "mini-soldering-wave", and with which one can solder a whole row of legs in one ongoing movement



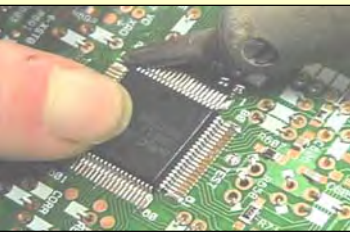
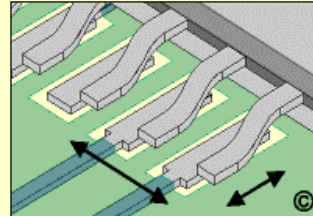
1. Cleaning of the soldering surface:

Remove all possible soldering residues (caused by desoldering) and make all the paths nicely even by going over those paths with the soldering bit. (without adding solder)



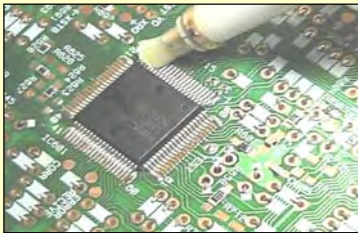
2. Positioning of the IC:

Position the IC on the patterns. This has to be very precise. A little movement can cause serious problems.

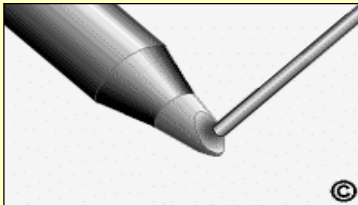


3. Fixing of the IC:

Fix the IC on the PCB, by "temporarily" soldering some legs on both sides.



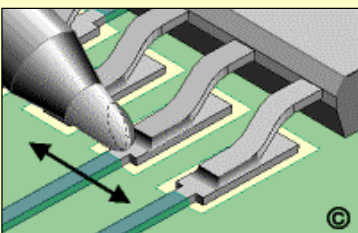
4. Add sufficient flux on all sides.



5. Filling of the bit and start of the soldering:

Fill the special (concave) soldering bit with solder.

Now start a slow dragging movement from one leg to another. Pay attention that the solder nicely moves up on the legs of the IC.

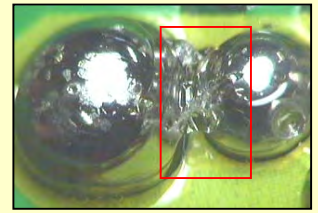
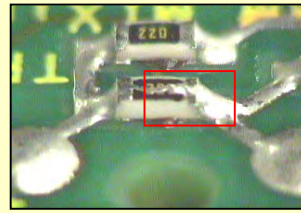
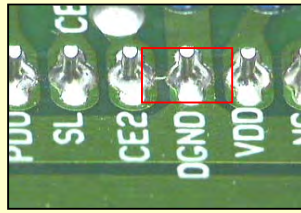
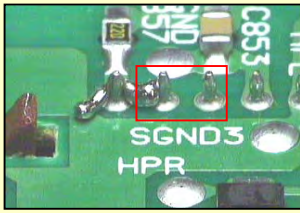


If the PCB is equipped with a "soldering thief" (a soldering land that is positioned next to the last leg), one has to solder in the direction of the soldering thief, so that at the end the possible surplus of solder flows on this soldering thief and no short circuit is created on the last two legs of the row.

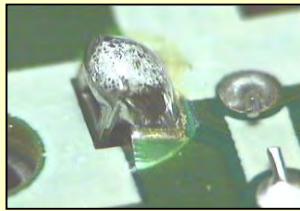
f) Incorrect soldering :

For certain soldering problems or soldering mistakes, specific terms are used:

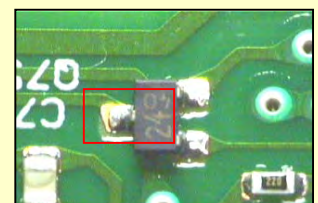
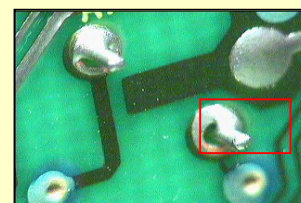
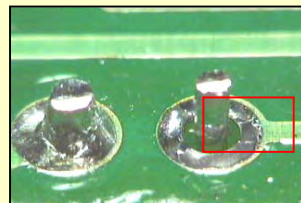
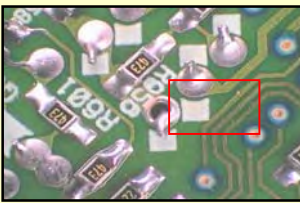
SOLDER BRIDGE



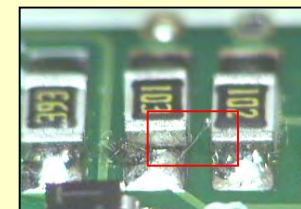
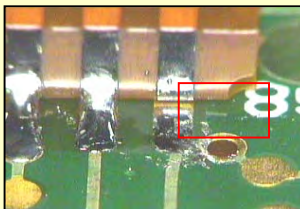
COLD SOLDERING



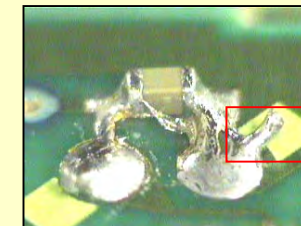
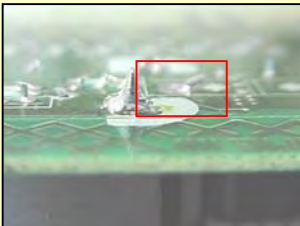
HALF SOLDERING OR DRY SOLDERING



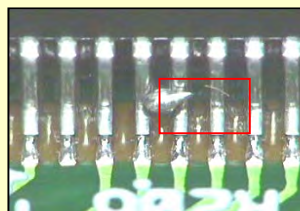
NO SOLDERING



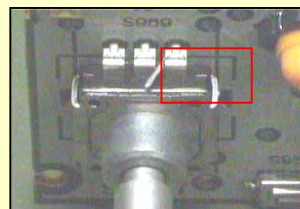
SOLDERING HORN



SOLDERING BALL OR SOLDERING SPLASH



SOLDERING WIRE SHORT CIRCUIT



7) (De)soldering with warm air and soldering paste:

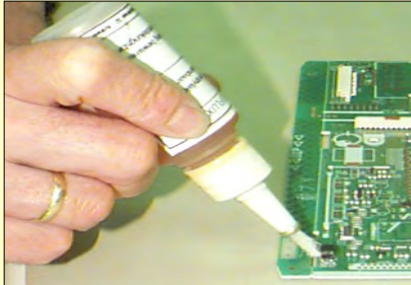
In some cases it is impossible to solder or desolder certain components with a classical soldering iron or a normal desoldering station.

This is often the case for SMT components, with contact legs (partly) underneath the component.

In such a case one has to use a (de)soldering appliance that uses warm air or infra-red heat.

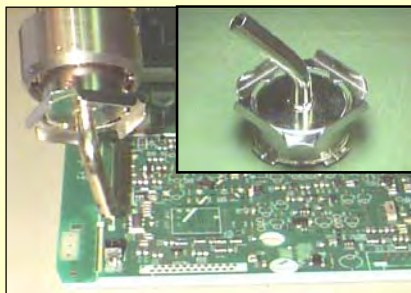


*SMT component
with contact surfaces
beneath the component*



1. Fluxing of the component:

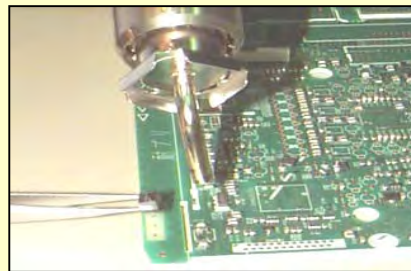
To have a good temperature conductance during warming up, the soldering surfaces need to be moistened with flux. If these surfaces are partly underneath the component, flux can be put on the borders of the component.



2. Warming-up of the soldered surfaces:

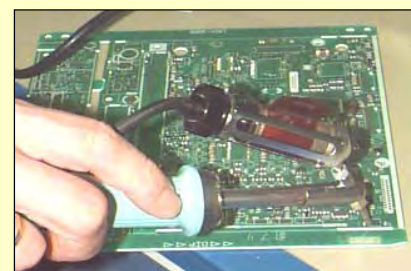
Use a "pointing nozzle" and point it at the component you want to remove. Keep a distance of 1 cm between the nozzle and the surface you want to warm up. Choose the temperature of the warm air e.g. +/- 340°C. (dependant on the temperature profile of the compents.)

Pay attention : if the contact surfaces are partly under the component, it is necessary to warm up the body of the component. Often the component is not useable afterwards.



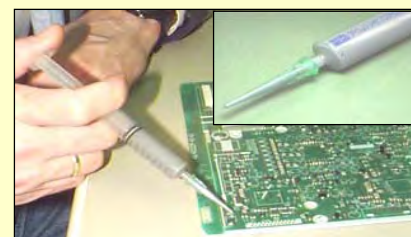
3. Removal of the component

When the solder (paste) has melted, the component can be removed with a pair of tweezers.



4. Cleaning of the soldering surfaces:

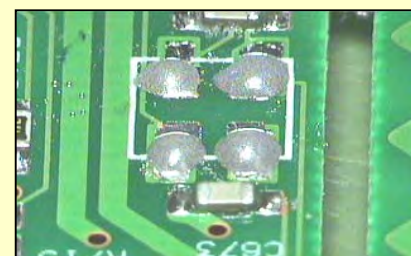
Remove all redundant soldering paste with a classical desoldering station.



5. Adding soldering paste:

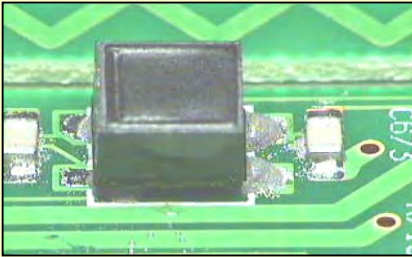
Add with a measured squirt the necessary soldering paste on the soldering lands.

Pay attention: soldering paste needs to be stored in strict circumstances. (see the instructions of the supplier)



6. Checking the quantity of soldering paste:

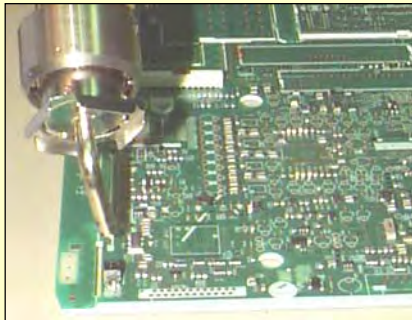
Check the quantity of the added soldering paste. Only the contact surfaces should be covered with soldering paste. Too much soldering paste can cause a short circuit during "re-flowing".



7. Positioning of the component

Position the new component carefully with the contact surfaces in the soldering paste with a pair of tweezers.

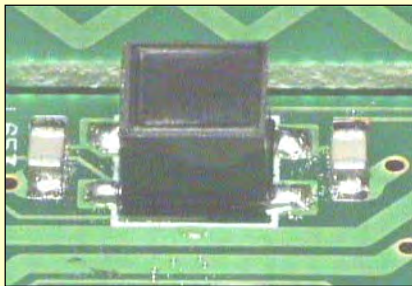
Position the component by the guide lines on the PCB.



8. Reflowing of the component:

Use a "pointing nozzle" and point it on the component you want to remove. Keep a distance of 1 cm between the nozzle and the surface you want to warm up. Choose the temperature of the warm air e.g. +/- 340°C. (dependant on the temperature profile of the component.) Warm up until one sees that the soldering paste is active or flowing. The result should be a good soldered joint.

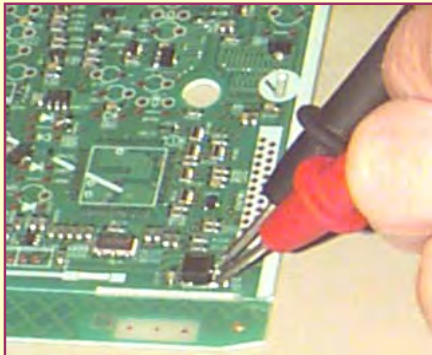
Pay attention: For most of the warm air soldering appliances one can choose the air pressure. The speed should be minimum, otherwise there is a possibility of blowing the component away.



9. Checking of the soldering:

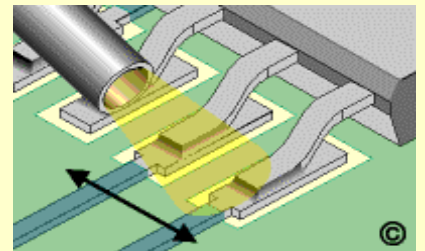
If possible, check the soldered joints.

Good soldering shines and has flowed evenly.



10. Checking of the electrical connection

If possible check the electrical connection with a meter.



Example of a "warm air soldering appliance": PACE.



8) Lead free soldering

Introduction.

Normally all solderings (mechanical - and hand soldering) were executed with soldering material that contained lead. (40 % lead / 60 % tin)

But lead is toxic and therefore damaging for humans and for nature.

Hence European directives were made in which companies will be obliged to use soldering techniques without lead after July 2006.

Soldering without lead is relatively new in the world of electronics.

Lead-free solder:

If no lead is present in the soldering wire, this has to be replaced. The soldering wire needs to contain another metal, like SILVER & COPPER. (96,5 % tin / 3% silver / 0,5 % copper)

This new composition has the advantage that it is no longer toxic and that the soldering connections are stronger. (lead is relatively weak). But this new composition also has some negative consequences:

- 1) The cost is higher (silver and copper alloys are more expensive than lead)
- 2) The joints look different (more granular instead of shining)
- 3) The melting temperature is higher

One of the main points of interest is the higher melting temperature. One would think that as a consequence of the higher melting temperature of the solder, also the soldering temperature needs to be raised. This however is not always allowed! Some components are only able to handle a certain maximum temperature for a certain time.

In practice:

- You can use your original soldering station if you can reach the correct temperature at the soldertip
- The soldering bit has to be a bit larger than a soldering bit for soldering with lead.

Pay attention: **Solder with lead and solder without lead can never be mixed.**

9) Temperature specifications of the soldering bit

Solder with lead

Process	Bit Type	Solder	Min	Center	Max
Pins	ETB / ETCC / 1121-0519	UOS-014	340°C	380°C	400°C
LCD	ETF / ETCC	UOS-005	320°C	340°C	360°C
OEL Display	ETCC	UOS-004	280°C	290°C	300°C
Connector	ETL / ETF	UOS-005	320°C	340°C	360°C
Flexible PCB	ETF	UOS-004	280°C	300°C	320°C
IC's & QFP IC's	1121-0490	UOS-005	280°C	300°C	320°C
Removal bridge	ETB / ETCC	UOS-005	320°C	340°C	360°C
Lights	ETF / ETB / 1121-0519	UOS-005	280°C	300°C	320°C
SMT/SMD repair	ETL / ETF	UOS-005	280°C	300°C	320°C

Temp. specifications Pioneer standard ZES-A015 & ZES-B016

Solder without lead

Process	Bit Type	Solder	Min	Center	Max
Pins	LTB / LTCC	UOS-026	400°C	410°C	420°C
LCD	LTF / LTCC	UOS-027	320°C	340°C	360°C
OEL Display	LTCC	UOS-028	280°C	300°C	320°C
Connector	LTL / LTF	UOS-027	320°C	340°C	360°C
Flexible PCB	LTF	UOS-028	280°C	300°C	320°C
IC's & QFP IC's	1121-0490	UOS-027	280°C	300°C	320°C
Removal bridge	LTB / LTCC	UOS-027	320°C	340°C	360°C
Lights	LTF / LTB	UOS-027	280°C	300°C	320°C
SMT/SMD repair	LTL / LTF	UOS-027	280°C	300°C	320°C

Temp. specifications Pioneer standard ZES-A043

Types of soldering wire:

With lead	UOS-014 (1 mm) + UOS-005 (0.8 mm) + UOS-004 (0.5mm)
Without lead	UOS-026 (1 mm) + UOS-027 (0.8 mm) + UOS-028 (0.5 mm)

10) Types of soldering bits:



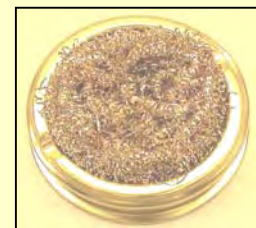
11) Soldering devices:



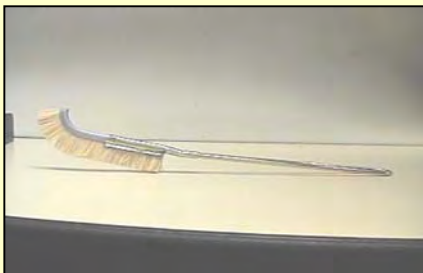
"Clean-o-point": for automatic cleaning of the soldering bit with 2 rotating sponges



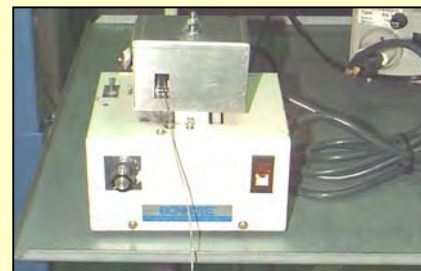
"Flux dosing bottle": for easy adding of flux (with brush)



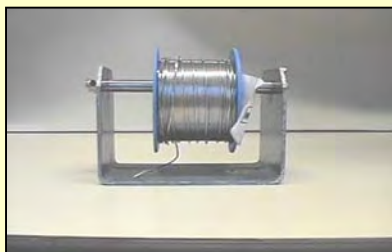
"Bit cleaner": for drying and cleaning of the soldering bit



"Brush": for removal of possible soldering residues after soldering



"V-cutter": for making a cut in the soldering wire, in order to reduce the formation of little soldering balls



"Solder dispenser": for a simple supply of soldering wire



"Tweezer-copper bit": handy tool for the removal of SMD/SMT components.



"Warm air desoldering appliance": for easy desoldering of flat-package IC's



"Desoldering appliance": for easy desoldering of point solderings



"Soldering magnifying glass": for a good view during soldering