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The Science of Soldering.

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Abstract: This study has dealt with the basic techniques and description of soldering. Soldering is a fundamental process of connecting the components to electronic circuits by using the filler material. The present work deals with applications of various soldering equipment and serves as a key to guiding beginners and professionals to identify the various types of electronic components and how to solder them properly on various types of printed circuit boards.

Index Terms - **Soldering, Printed circuit board, Solder Preforms, Soldering Equipments.**

I. INTRODUCTION

INTRODUCTION

Soldering is the process of joining multiple metallic surfaces together by using filler metallic material. This process is basically used in every industry involving electronics usage that can be used either to manufacture the Printed circuit board (PCB) with components or to repair the PCB. Various types of PCB & electronic components require different soldering skills and materials.

NEED OF THE STUDY.

This study will help beginners and professional individuals understand the concepts of soldering, usage of equipment & how the techniques of soldering change with the change in PCB and components. Moreover, it will provide a comprehensive way of understanding and a one-stop destination for all queries.

LITERATURE REVIEW.

Definition:

Soldering is the process of joining multiple metallic surfaces together by using filler metallic material called solder.[1]

History & Evolution:

This is an ancient art discovered around 5000 years back at Mesopotamia, used majorly in making jewellery, weapons, utensils & farming tools. The solder metals were produced using burning coals on open flames. Later in 1896, The American Electrical heater company patented their soldering irons but that was unavailable for industrial use.

Finally in 1921, Mr. Ernst Sachs developed& manufactured the first commercially available electric soldering iron ERSA. That made the task easy & more approachable. Soldering was not a standalone subject earlier, it required the knowledge of thermodynamics, chemistry, mechanics & metallurgy but in the last century this became an independent subject.

Leading the evolution soldering today is performed by Solder preforms with good quality machinery. Coining is a top-class solder preform manufacturer owning expensive libraries & dies[2].

How is soldering done & Basic tools required:

Solder material (metallic) is melted by using heat from an iron connected to temperature controller. The melted solder is placed at the point of soldering & cooled further creating a conductive joint.

Moving ahead with the basic tools for soldering includes a solder, flux, soldering iron, soldering station, soldering tweezers, solder preforms.

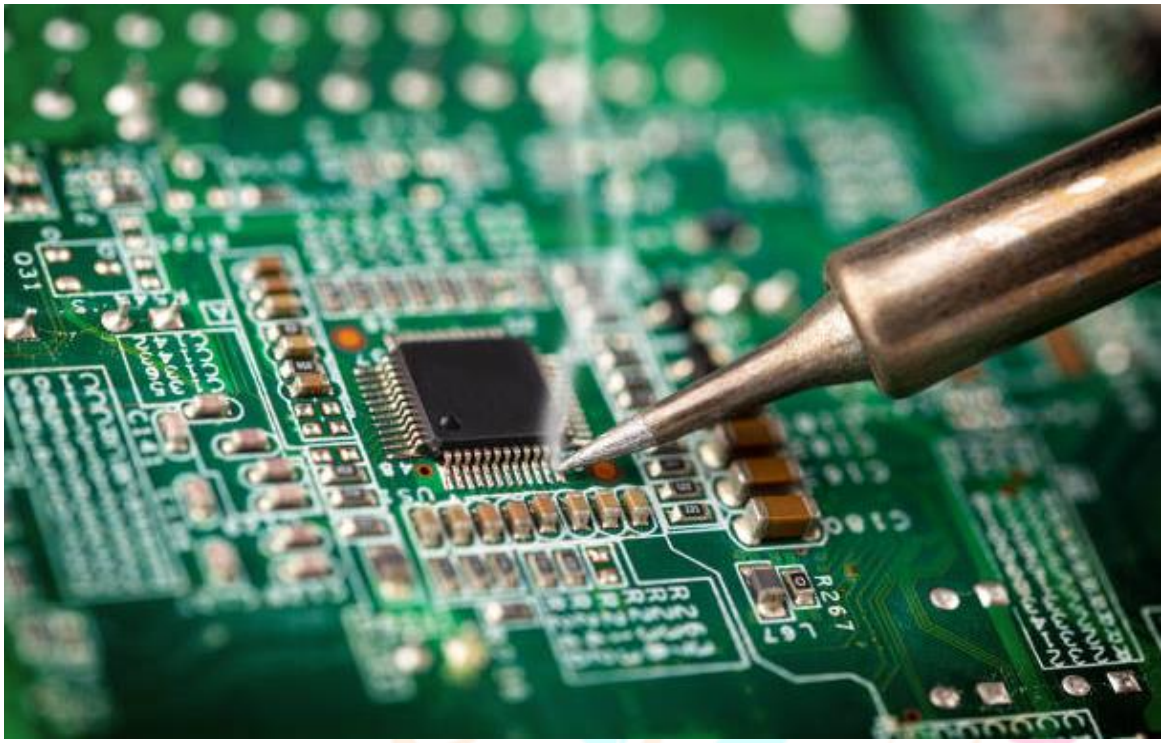

Fig 1. Soldering Process.

First one is the solder, word comes from English word soudur, French word solduree and Latin word solidare[3].
This is a fusible metal alloy (made of lead & tin generally) is melted at the place where joint needs to be formed. It adheres to & connects the pieces after cooling. This generally has a lower melting point than the corresponding components to be joined & also the better resistance to oxidation & corrosion along with favorable electrical characteristics.

Fig2. Solder Material

The solder material decides the type of soldering to be performed i.e. alloys having a melting point range of 90 to 450 degrees centigrade are called soft solder and soldering process is called soft soldering whereas if the melting point of alloys is more than 450 degrees centigrade then it is called hard solder, and the soldering process is called hard soldering. Hard soldering can also be renamed Brazing or silver soldering.
Soldered joints should not be disturbed if the solder material is in melted state as that would lead to poor electrical connection. Solder is available in the form of wires or thin foil shapes which can be placed at required point and melted accordingly. Plumbers used bars of solders, but jewellers used thin sheets of solders. Various types of solders are available such as: lead based, lead free, hard solder.
Lead based solders are tin lead solders (Soft solders) are commercially available with varying tin concentrations. The increased tin concentration ensures that solder has greater tensile & shear strength. Commonly used variant for electrical soldering purpose is 60/40 Sn-Pb melting at 190 degrees centigrade & 63/37Sn-Pb for electronic work.
Later lead was prohibited, considering the harmful effects of lead & health concerns of individual.
Lead free solders: Replacing the lead from the lead-based solder with copper, silver, bismuth, indium, zinc, antimony leads to the formation of lead-free solder alloy. This solder is inappropriate for usage in aerospace, military & medical projects due to its less strong joint & can suffer fatigue under stress. Pb-Ag-Cu solders are used by two thirds of people for soldering, addition of fourth element in this solder can be done based on requirement. They are increasingly used due to regulatory requirements by European ROHS & environmental benefits. Extensively used in consumer electronics. Hard solders are used for brazing as they melt at high temperatures. Alloys of copper with zinc or silver are most used as hard solder. They don't contain lead in them & can vary in hardness. Common solder formulations on the basis of lead and tin content are: 63/37,60/40,50/50[4] [5].

The second one is Flux which is a reducing agent /purifying agent that can be used for extraction purpose & joining[6]. Basically, flux is made up of sodium carbonate, potash, charcoal, coke, borax, lime & lead sulfide. This reduces the chances of formation of oxides on the surface of molten metal & is also used as heat transfer medium to facilitate the heating of joint by soldering tool.

Thus, in soldering the flux serves a threefold purpose by removing oxidized metal from soldering surface and prevents air entry & further oxidation & improves wetting characteristics of solder[7].

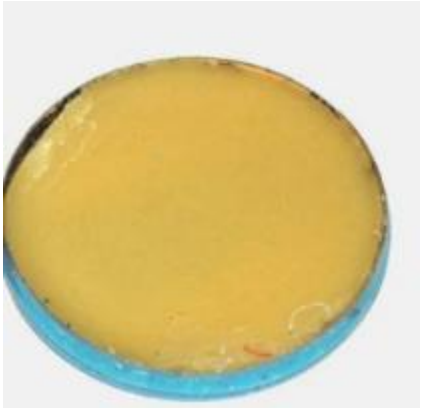

Fig 3. Soldering Flux.

For hard solders we require a faster or aggressive flux to provide a physical barrier. Traditionally we use borax for the same. Composition of flux is decided by surface of soldering & the material used. Fluxes include activators for dissolving metal oxides, vehicles to act as an oxygen barrier to protect hot metal surface against oxidation, solvents to facilitate processing & deposition of joint & additives to modify flux properties. They can be organic & inorganic. Organic fluxes are used for soft soldering whereas inorganic flux is used for brazing or hard soldering. E.g. Borax, borates, fluoroborates, fluorides etc.
Most used flux is rosin flux or resin flux that majorly includes rosin (a material having good flux properties) and tends to soften between 60 to 70 degrees centigrade. This is weakly acidic in molten form and dissolve thinner layers of oxides from copper. Wood rosin is preferred for flux applications, but tall oil rosin is used much due to its good thermal stability. Certain other acids & components can be added. There are grades of flux according to their activity capability e.g. R, WW, RMA etc. all these three grades are used for highly corrosive joints. Flux is generally standardized by European standard ISO 94541and the flux is labelled according to its flux type, base, activator & form [8] [9].

The third equipment is soldering iron which is a hand tool used for soldering by supplying heat to melt the solder. Composed of bit (heated metal tip) & a handle made up of insulator material. The iron gets heated up electrically by passing an electric current through a resistive heating element. They can easily heat up to a temperature range of 200 to 480 degrees centigrade so that solder melts easily. Typically, they consist of copper block with a shaped point, iron rod, wood handle [14]. Later, it was replaced by electric iron. In 1946 a soldering gun was developed that could be heated instantly for good & early soldering. Types of soldering iron: Simple iron, cordless iron.

Simple Iron: Low power iron, power rating of 15-35W and can't be used at high temperature, provides more heat for making soldered connections. This is heated by current flow through the cable.

Fig 4. Simple Soldering Iron.

Cordless iron: This is heated by battery and its power rating can be modified.

Fig 5. Cordless Soldering Iron.

Soldering irons can be kept on soldering iron stand to keep it away from flammable materials. The stand includes a cellulose sponge, flux pot for cleaning the tip. Tips are also called bits; these are interchangeable tips that vary in size and shape for different types of work. Basic shapes of tips include Bevel, chisel, conical[10].

Fig 6. Soldering stand.

Pyramid tips & chisel tips are for soldering sheet metal. Conical or tapered tips are commonly used for electronics work. Thus, we can say that tip selection depends upon the type of work to be performed. Concave tips prevent bridging in closely spaced leads. Copper tips dissolve gradually into solder with usage. But iron plated copper tips are popular due to their non-solvability by molten solders. Steel tips are not preferred due to their less heat holding capacity. Considering the usefulness of the tip, cleaning of tip also becomes necessary. Identifying the need of cleaning the tip is crucial[11]. If the tip is oxidized, flux is accumulated on it, solder metal will not melt on it & thus it should be periodically cleaned. So it is preferred to keep the tips of soldering iron tinned with molten solder & flux to avoid oxidation. [12].

Fig 7: Bits.

Things used for cleaning the tip variates according to the type of solder used i.e. for lead solder we require a wet sponge but for lead free solder we require cleaning by brass shavings [13]

The fourth one is soldering station which has a temperature control & consists of an electrical power supply, control circuitry for adjusting temperature & display & soldering iron. Along with all this there is a stand to keep the hot soldering iron & a wet sponge for cleaning [17][18].

Fig.8. Soldering Station.

Fifth is the soldering tweezers which are useful for soldering surface mount components with two terminals. They have insulated handles & metallic tips for holding the components.

Fig 9. Soldering Tweezer.

Another is a Solder preform which is an optional element, this is made up of solder alloys customized into shapes & dimensions according to applications. The size of preform is determined by the amount of solder needed. They are preferred for precise applications.

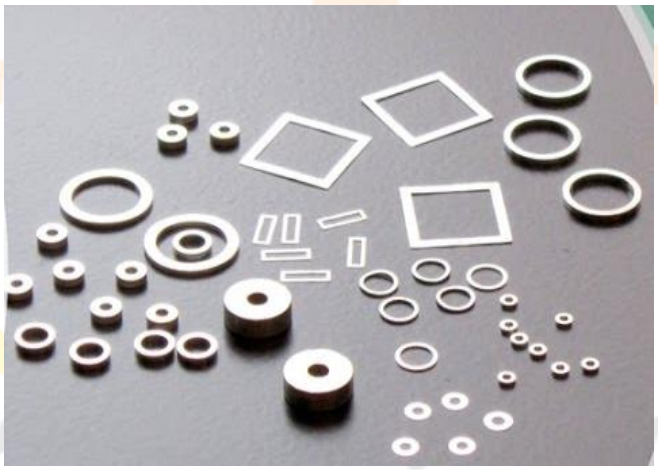

Fig 10. Solder Preforms.

Precautions taken during soldering:

- All soldering irons are not Electrostatic discharge (ESD) safe.
- Fumes released during soldering may have some lead content, especially if lead solder is used.
- Never touch a hot iron as it may lead to burns.
- Always wear eye protection gear[15][16][17].

Various components that can be soldered on PCB: Almost all the electronic & mechanical components are soldered on PCB. That majorly includes resistors, capacitors, diodes, transistors, Integrated Circuits (IC), Light emitting diode (LED), switches, inductors, batteries, oscillators, transformers, potentiometers etc.

Different types of PCB in focus are rigid PCB, flex PCB, rigid flex PCB, metal core PCB, Single sided PCB, Double sided PCB, Multilayer PCB. As the component changes, the type of PCB changes the soldering method changes accordingly. Moving ahead with the ways of soldering various components on PCB.

Soldering of various commonly used electronic components:

1. Fixed Resistors: The carbon composition and film wire bound resistors with bent through hole leads & they are inserted in PCB and then soldered. Thick & thin film resistors are directly soldered on PCB pads.
2. Variable Resistors: It includes potentiometers, rheostats, thermistors, varistors, photoresistors which are soldered by soldering the hole leads. They should be heated for a less duration of time & on clean PCB.
3. Ceramic Capacitors: Small sized & easy to solder directly on pads but proper dissipation of heat must be ensured.
4. Electrolytic Capacitors & Super capacitors: Polarized so polarity must be considered while soldering & reverse voltage can damage it.

All of these should have proper heat dissipation & soldering time must be minimum along with ensuring the proper polarity.

5. Integrated Circuits (IC): Place the IC carefully on the PCB so that pins are aligned with the marking. Fill the solder at the tip of the soldering iron. This will glide over the pins of IC & solder them by depositing perfect amount of solder.

Soldering techniques for various components on various PCB:

1. Rigid PCB & Flex PCB: Put the solder on the soldering iron tip & flow the molten solder to the joint ensuring a good connection, remove the iron after application of solder & keep it for solidification. The process of soldering is same as flex PCB as well but considering its flexibility we have to use low temperature & shorter duration of soldering. They also require support for holding during soldering to avoid damage. Moreover, cleaning the PCB is also required.
2. Rigid-flex PCB: Careful attention is required for heat management & component placement. The following steps must be followed:
    - Fix the PCB and choose the low temperature solder alloys.
    - Now heat the soldering iron to a minimum temperature required to melt the solder.
    - Apply flux.
    - Tin the tip.
    - Heat the joint & allow the solder metal to flow through the joint.
    - We can also use potting material to pot the joints and to avoid their flexing.
    - Use tweezers to align the components properly.
3. Metal Core PCB: These PCB require extra care due to their high heat dissipation capacity. Soldering iron must be heated to a high temperature & also preheated the joint. Apply the solder with the joints, after this clean the pads by flux. Place the component and let the solder cool down for the setting purpose. Heat dissipation must be considered for these types of PCB so they should have a better heat sink.
4. Single Sided PCB: The soldering process is like the general soldering process but avoid using excess solder as it can cause bridging & component should be properly placed along with good heat dissipation.
5. Double-Sided PCB: As the soldering needs to be done on both sides of the PCB so the process of soldering will be a bit different in this case this will include:
    - Deciding which components are to be placed on a particular side of PCB.
    - The side with complex & heat sensitive components should be started first. The components should be placed on one side and then on another side.
    - They should undergo reflow twice.
    - High temperature solder paste should be used for one side & low temperature for another side.
    - Use jigs to hold the PCB & place the components using a stencil or marking.
    - Cooling should be done & then soldering should be started on another side of PCB to avoid component displacement.

IV. Conclusion

Concluding to the study, the soldering is an interesting process that requires good skills and knowledge of materials for efficient and proper joints. The connection techniques change with the change in the type of PCB, and the components.

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