AUSTRALIAN NATIONAL UNIVERSITY
Department of Engineering

Soldering How To

Soldering Basics

Solder is used to join electrically conducting parts. The parts are first mechanically secured and then quickly heated with a soldering iron. The solder is applied to the heated surfaces and is allowed to melt the surfaces. The finished solder joint metallurgically bonds the parts and forms a highly conducting electrical connection and a strong mechanical joint between the metal parts. Examples of metal parts that require soldering are transistor/IC leads and PCB (Printed Circuit Board) track, wire and connector, or resistor/capacitor and tag board.

Soldering Equipment

Two types of *soldering equipment* are the *soldering iron* and the *instant heat soldering gun*. Most soldering irons are of pencil type construction and range in heater output power from 15 to 250W. A 40 to 60W soldering iron is suitable for small electronic work, for example, soldering components to a PCB. A 60 to 100W iron is suitable for larger electrical work, for example, wiring a mains cord to a connector. The cordless soldering irons used for field work are either powered by rechargeable batteries or by butane gas. The transformer isolated, grounded tip soldering irons with 12 or 24V heating elements are used for electrostatically sensitive electronics work, for example, soldering MOS devices. The temperature controlled soldering irons are employed for precision temperature sensitive soldering work, for example, soldering surface mount device (SMD) chips onto a PCB.

The *soldering iron tip* transfers thermal energy from heater to the soldering connection. Most tips are some copper alloys for their excellent thermal conductivity. The tips are available in different shapes and sizes suitable for different types of work. For fast and optimal heat transfer, the tip should be of the largest possible diameter and the shortest reach suitable for the type of job. The mains powered soldering iron tips are usually connected to GND for operator and component safety. The grounded tip protects voltage and current sensitive components.

The soldering *tip temperature* is usually set between 700 and 800 deg. F (370 to 425 deg. C). This is substantially higher than melting point of most solders (400 deg. F). Using a higher temperature stores heat in the tip which speeds up the melting process and allows proper formation of inter-metallic layer of the parts and solder.

The soldering iron you will be using in the lab is *Weller WTCPT* (manufactured by Cooper Tools, Australia) mains powered, transformer isolated and temperature controlled.

A ferromagnetic temperature sensor attached to the tip and a permanent magnet inside the pencil in close proximity with the sensor is used for ON-OFF temperature control. The heater is rated at 24V/48W and the tip used is 1.6 mm screwdriver type having temperature rating of 700 deg. F (The bottom end of the tip is marked with '7').

For care and safe use of soldering equipment, Thou shall learn and follow, *without fail*, Ten Commandments:

1. **Do not remove tip from soldering iron when power is *ON.*** Causes heating element to rise in temperature to approximately 1300 F resulting in thermal shock and reduced heater life.

2. **Do maintain a damp (NOT drenched) iron sponge (preferably with de-ionized water).** A drenched sponge will bring the temperature of the tip down too drastically, causing thermal shock and reduced tip life.

3. **Do not disconnect soldering iron from base unit when power is turned *ON.*** Disconnecting or reconnecting the soldering tool from the base unit with power applied may cause a short between non-compatible pins resulting in damage to the base unit or pencil.

4. **Do maintain a coating of solder on working area of soldering iron tip**. Protects the tip from oxidation.

5. **Never drop soldering iron while heated.** Dropping the soldering tool while heated may cause thermal/mechanical shock to the heater, sensor, or tip (fractured plating).

6. **Do not throw soldering iron into soldering tool stand.** See Commandment 5.

7. **Never use soldering iron as a crowbar or pry tool.** Could chip or pit finish on tip, rendering it useless.

8. **Using sharp or serrated objects to remove tip from soldering iron is forbidden.** See Commandment 7.

9. **Honour your KGB (Known Good Base).** Do not plug a non-working soldering iron into a KGB. Could cause damage to the base.

10. **Turn station down to lowest setting during daily usage when not being used.** Turning the station down during non use periods will prevent severe thermal cycling of the tool. However, tools not being used for extended periods of time should not be left on indefinitely.

Soldering Material

Solder is an alloy of two or more metals and is used to join metallic surfaces together when melted by soldering iron. The most common alloy used is 60/40-Tin/Lead and has a melting point of 374 deg. F (190 deg. C). Most soldering jobs can be done with flux cored solder (solder wire with flux in multiple cores). The surfaces to be joined have to be cleaned of dirt, grease, rust, soot etc. before soldering. The flux aids in cleaning oxides off the surfaces to be soldered.

Solder should have following *qualities* for best performance.

- Diameter: (0.5 to 1.5 mm) suitable for the job.

- Whetting: flow over the metal surfaces bonding at every point.

- Temperature: melt and wet the metal surfaces at a temperature lower than the soldering iron tip temperature.

- Strength: hard but not brittle.

The organic, non-corrosive *fluxes* are used in electrical soldering. The most common flux used is a rosin flux (a kind of resin-organic compound insoluble in water) which is non-corrosive and non-conductive. Prior cleaning of electrical components is generally not necessary when using active rosin cored solder. However, flux will not remove grease or oil from surfaces. It only removes thin oxide/tarnish. The solder is also available without the inner flux core, for use with liquid/solid flux.

Soldering Techniques

Half of the secrets of successful soldering are a CLEAN soldering iron tip and CLEAN metal surfaces to be soldered. The other half of the secret lies in proper soldering techniques.

- Ensure that the surfaces of parts to be soldered are thoroughly CLEAN. Use wire wool or fine emery cloth or alcohol to clean the surfaces off dirt, oil, grease etc. if necessary.

- Solder being a soft material, a good mechanical connection of parts to be soldered, prior to soldering is essential. Twist the wire strands together, wrap the wires around each other or around terminal post and bend the component leads to 45 deg. after inserting in PCB holes.

- **DO NOT APPLY SOLDERING TIP HEAT DIRECTLY TO THE SOLDER.** This will cause the flux to evaporate and the solder will not whet the surface to be soldered. Apply the heat to the component leads/tags/wires and melt the solder onto the surface to be soldered.

- **DO NOT INHALE NASTY SOLDER FUMES !**

- **DO NOT APPLY EXCESSIVE PRESSURE ON THE JOINT** while soldering.

- When the solder has flown into the joint, first remove the solder wire away and then smoothly slide the iron away leaving the joint neat. The soldering process should be finished in 2-3 sec. for electronic soldering.

- To avoid joint/wire moving while being soldered and while the joint is setting, a soldering aid tool such as long nose pliers can be used to hold component/wire in place. After solder wire and iron are removed from the joint, you may blow air on the heated soldering joint to speed the process of setting. It will only take 2-3 sec. for setting of the joint.

- A **GOOD SOLDERING JOINT** is characterized by a smooth shining surface of uniformly flown optimum amount of solder.

- **DO NOT OVERHEAT ELECTRONIC COMPONENTS WHILE SOLDERING.** Hold the wire/component with long nose pliers to dissipate heat away from the component.

- **DO NOT APPLY EXCESS SOLDER.** Excess solder can fill up sockets, freeze switches, cause short circuits and result in a dry (dull finish) soldering joint.

- To de-solder a joint, apply heat and use long nose pliers to separate joint. Remove used solder from the surfaces using soldering iron and de-soldering tools. Use new solder when re-soldering.

Check out "Better Soldering" for the following details.
- How to care for your tip.
- The correct way to solder.
- The operator's effect on the soldering process.
- Reliable solder connection.
- Key points to remember in soldering.

Circuit Board Equipment

Two types of copper-clad *laminates* are commonly used for circuit boards, synthetic resin bonded paper phenolic and fibreglass-epoxy. The fibreglass-epoxy type laminate has superior electrical and mechanical properties compared to the other type.

The types of circuit boards used for prototyping are tag-board, proto-board and solder-less breadboard. The *proto-board* you will be using for this lab is 1.6mm thick, single sided paper phenolic type. This board has horizontal busbars for connecting power supply rails, ground rail and other common rails. The hole-pitch is 0.1 inch suitable for IC (integrated circuit). The vertical busbars are used as circuit nodes. The components and wires are inserted into appropriate holes from component side (opposite to copper track side) and soldered onto respective copper pads.

The *solder-less breadboard* you use in other labs also has similar busbars and hole-pitch. The components (DIP (Dual Inline Package) ICs, resistors and capacitors) and single-strand wires (diameter 0.3-0.8mm) are inserted into appropriate holes and held by spring loaded nickel-silver contacts. Two or more breadboards can be snapped together to provide vertical or horizontal expansion for larger circuits. This type of board is a convenient tool used in quick prototyping and testing, however has limitations in testing low voltage DC/high frequency AC circuits due to DC drift/AC interference respectively. These limitations are overcome in a proto-board due to compact layout and short wire lengths.

The common *Printed Circuit Board (PCB)* is 1.6mm thick with copper tracks on one or both sides and holes drilled through the laminate for component leads.

A number of *PCB fabrication methods* are available to suit the application.

- Draw tracks and pads using etch resist pen/pads/tracks or oil paint/brush and etch off unwanted copper in a ferric chloride bath. Used for one-off single sided small prototype boards.

- Design PCB artwork (using Protel/PSpice or similar S/W), take a laser print, melt the print toner onto copper-clad laminate with smoothing iron, etch off uncoated copper. Used for small quantities of single/double sided small PCBs for prototypes. The plated through holes (PTH) is not possible. The min. track size is limited to approx. 0.02 inch and accurate drilling of a large no. of holes is difficult and time consuming.

- Department of Engineering has NC controlled circuit-board cutting machine which can produce circuit patterns by cutting and grinding away copper around each track/pad. The holes are drilled by machine but PTH is not possible, also min. track size is limited. This is a convenient method for digital logic circuits. The connection from one side to the other is possible with a small wire connection through the hole soldered on both sides. However, the large areas of copper left around tracks increase the risk of shorting adjacent tracks while soldering and also cause leakages/stray impedance's and can affect low voltage DC/high frequency AC circuit performance.

- Screen Printing Method: The screen with transparent circuit pattern is produced using photographic technique and etching. The circuit pattern is transferred onto PCB laminate using etch resist ink and a squeeze. Subsequent etching of board produces circuit board. This method is economic in producing single sided boards of medium complexity in small to medium volume.

- Commercial circuit board manufacturers use a process called photolithography and routinely produce multilayer, PTH boards with tracks as thin as 0.005 inch. PTH is accomplished by electroplating the inside of the hole and enable circuit connection from one side to the other or between two or more layers without the use of jumper wire. Complex and large circuits can be reliably produced in large quantities using this method. The board edges are milled using NC machines to produce accurate sizes. The cost of producing small quantities is high due to one development and tooling costs, however, large quantities can be produced economically.

Circuit Assembly Techniques

The *soldering joints* are between a wire and a tag, wire and circuit board pad, component lead and pad or a connector pin and pad. Most component leads/tags and wires are tin/silver plated for easy solderability. The circuit board patterns are also tin/silver plated for excellent whettability.

The *wires* are stripped off insulation using a wire stripper. The stripped length should be just adequate for the soldering joint to be made. Excessive length of exposed copper can cause short circuits and also the wiring joint can be easily snipped after soldering. The multi-strand wires are twisted together for mechanical integrity and solder coated before inserting into PCB/component tag holes and soldering. Component tags are also solder coated prior to soldering for ease of whettability. The wire should be bent by 90 deg. for a tag joint and by 45 deg. for a board joint. (More than 45 deg. bend for a board joint makes it difficult to repair) Soldered copper wires should not be bent at the point they emerge from soldering joint as they can be easily snipped. Wire joint should be made quickly with minimum heating to avoid damage to wire strands. Excessive solder would cause dry soldering joint and also a possible short circuit.

The resistor/capacitor *component leads* should not be bent closer than 1-2 mm to the components for mechanical strength. The lead bending/cutting machines are employed in electronic circuit board production. The leads of heavier components are bent with a kink for enhanced mechanical support. The solder joint should not be made closer than 3-5 mm to the components as the heat of soldering could cause damage. While soldering *semiconductors/ICs*, spread the heat and finish the soldering quickly to avoid overheating and possible damage/drift of component. ICs are commonly mounted on sockets for ease of dis-assembly. A grounded tip low voltage soldering iron, grounded desktop and wrist ground strap are used while soldering electrostatically sensitive devices such as MOS transistors.

While *soldering components* to PCB/breadboard, finish soldering quickly (2-3 sec). Excessive heat through prolonged soldering can easily cause copper foil to lift from the laminate. The components are mounted either vertically or horizontally on PCB. Vertical mounting increases component density and reduces amount of heat absorbed by the components while soldering. The horizontal mounting gives better mechanical support to components and less susceptibility to damage through vibration. The component leads are bent at 90 deg. near the components before inserting into PCB. The leads are bent at 45 deg. on solder side of PCB before soldering. The excess lead length is snipped very close to the soldering joint. The track side of assembled circuit board is cleaned off excess flux/impurities with an organic solvent.

A *crimped wire connection* is used as a substitute to soldering joint. This is a commonly used wire termination and is also used to connect multi-core flat cables onto crimp connectors. A wire should never be both soldered and crimped to a connector.

Testing and Trouble-shooting

The assembled circuit board is first visually inspected for any shorts/opens in the circuit. The circuit is then tested using an Ohmmeter. This is to ensure that power supplies, inputs and outputs are not shorted to ground or to each other. This is an important step before powering up the circuit and avoids costly damages to circuit components.

The circuit power supplies are checked after powering up and circuit is checked for its intended function using multimeter and/or oscilloscope. It is a good practice to provide test points/probes for power supplies, inputs, outputs and critical circuit nodes. The circuit is tested in a stepwise manner isolating it from output stages where possible. Never test circuit impedance's while circuit is powered up. To test circuit node impedance, isolate it from other nodes. Consider loading effects while testing the circuit using multimeter/oscilloscope. For example, measuring voltage across 1 M-Ohm resistor with a multimeter having 10 M-Ohm input impedance will drop the voltage by approx. 10%. Also, consider frequency response of meter while measuring AC voltages. Most multimeter AC ranges are calibrated to RMS of sine and are grossly inaccurate in measurement of non-sine signals such as square wave. True RMS AC voltage function is required to accurately measure non-sine signals.

Use single point grounding to avoid grounding errors in low voltage measurement. Also, use neat compact layout and short wire lengths in high frequency AC circuits.

Use appropriate test prods to check circuit voltages and avoid damages due to short circuits in powered circuits. Take extra precaution while checking voltage onto IC pin. Switch off power to the circuit while replacing an IC or a component or while doing solder rework on PCB.