Basic Electronics Series

Soldering Done Right

Housekeeping

- Emergency Exits – look around yourself and familiarize yourself with the most direct line of egress in an emergency
- Side Conversations – please refrain from conducting secondary or side discussions, as it takes away from the Forum benefit for other attendees
- If you have a question, ask it at the time that it occurs to you instead of waiting

SAFETY FIRST!

- Starting out, we will talk about safety as the first topic of conversation, because safety is and should be the number one priority and consideration when soldering
- As mentioned, be sure that you know where your exits are – here and at your shop
- Be sure to wear…
  - eye protection
  - long pants
  - sturdy shoes with uppers

SAFETY FIRST!

- Be actively aware of flying component lead stubs when clipping leads after soldering them
  - Hold the clipping to prevent it from flying – ***eye hazard!***
- Be actively aware of splattering or dripping solder droplets whenever the work is heated enough to melt the solder
  - It does not take much force to send solder droplets flying through the air – ***burn hazard!***

Show of Hands…

- How many of you feel that you already know how to solder?
- How many of you have had difficulty in one or maybe a few particular soldering jobs?
- How many of you have had trouble getting solder to "stick" to the workpiece?
- How many of you have had trouble in de-soldering certain components?

Terminology

- *Alloy* – a mixture of two or more metals so combined as to result in a new metal with unique properties of its own
- *Core* – the hollow central portion of a length of wire solder, usually filled with a rosin flux for electronics work solder
- *Dwell* – the period of time during which the soldering iron heat is applied to the work

Terminology

- *Eutectic* – having a melting point, as an alloy, that is lower than the individual melting points of the constituent metals of the alloy
- *Flux* – a cleaning and wetting agent used in the preparation of metals for joining by use of solder
- *Heat Sink* – a device used to carry heat away from a component as a means of thermally protecting the component

Terminology

- *Melting Point* – the specific temperature at which a metal changes state from a solid to a liquid, usually a different temperature than that at which the reverse process occurs
- *Rosin* – a resin produced by certain plants, mostly coniferous trees, consisting of organic acids and terpenes and used as a solder *flux*

Terminology

- *Solder* – as a noun, solder is the filler metal used to join two or more other metals, and as a verb, to solder is to join two or more metal objects through the use of a low-melting point filler metal
- *Tin* – as a verb, to tin is to apply a coat of molten solder to a component's lead, to a wire, or to the tip of a soldering iron

What *is* Soldering?

- Joining together two metals that have melting temperatures higher than the melting temperature of the filler metal alloy
- Two types of soldering…
  - Hard soldering
    - Brazing, silver soldering
  - Soft soldering
    - Lead or lead-free soft metal soldering

What *is* Solder?

- A fusible metal alloy used to form a permanent bond between parts
  - Tin (Sn) and lead (Pb)
  - Tin (Sn) and…
    - … Antimony (Sb)
    - … Copper (Cu)
    - … Silver (Ag)
    - … Bismuth (Bi)
    - … Indium (In)
    - … Zinc (Zn)

Hard Solder

- Melting point of hard solder is above 450°C
- Most common are alloys of:
  - Copper (Cu) and Silver (Ag)
  - Copper (Cu) and Zinc (Zn)
- Often used when metals to be joined cannot be welded
- May leave brittle joint

Soft Solder

- Used for electrical and electronics work
- Commonly uses leaded solder, though lead-free is becoming more common
  - Lead-free is required in EU for all consumer-grade products in accordance with RoHS (Restriction of Hazardous Substances) Directive
- Use of lead-free solder in USA may earn tax benefits to companies doing so

Leaded Solder

- Most common alloys, by weight, are
  - 60% Sn / 40% Pb
  - 63% Sn / 37% Pb
- 60/40 solder melts at 188°C (370°F)
- 63/37 solder melts at 183°C (361°F)
  - 63/37 SN/Pb is an eutectic mixture – it has a melting point lower than melting points of its constituent metals – and has the lowest melting point of all leaded solders

Lead-free Solder

- Alloys of tin (Sn) and other metals as mentioned earlier
- Have melting points 50°C to 200°C higher than those of leaded solders
- Prohibited in critical applications such as aerospace and defense and in most medical applications, due to the high rates of stress failures of lead-free solder joints

Flux

- Almost all electric or electronic soldering uses rosin flux, a product of pine sap
- Flux cleans the metal and provides for proper *wetting* of the surfaces to be joined
- Wetting allows solder to adhere properly to the metal surface
- Flux is found in the core of electronic wire solder, but additional flux can be added

Flux

- Rosin flux can be in a paste form or in a viscous liquid form
- Paste flux can be brushed on or spread on with a flat and narrow flexible blade
- Liquid flux can be brushed on or it can be applied with a syringe
- Keep unused flux clean and covered when not in use to protect against contamination

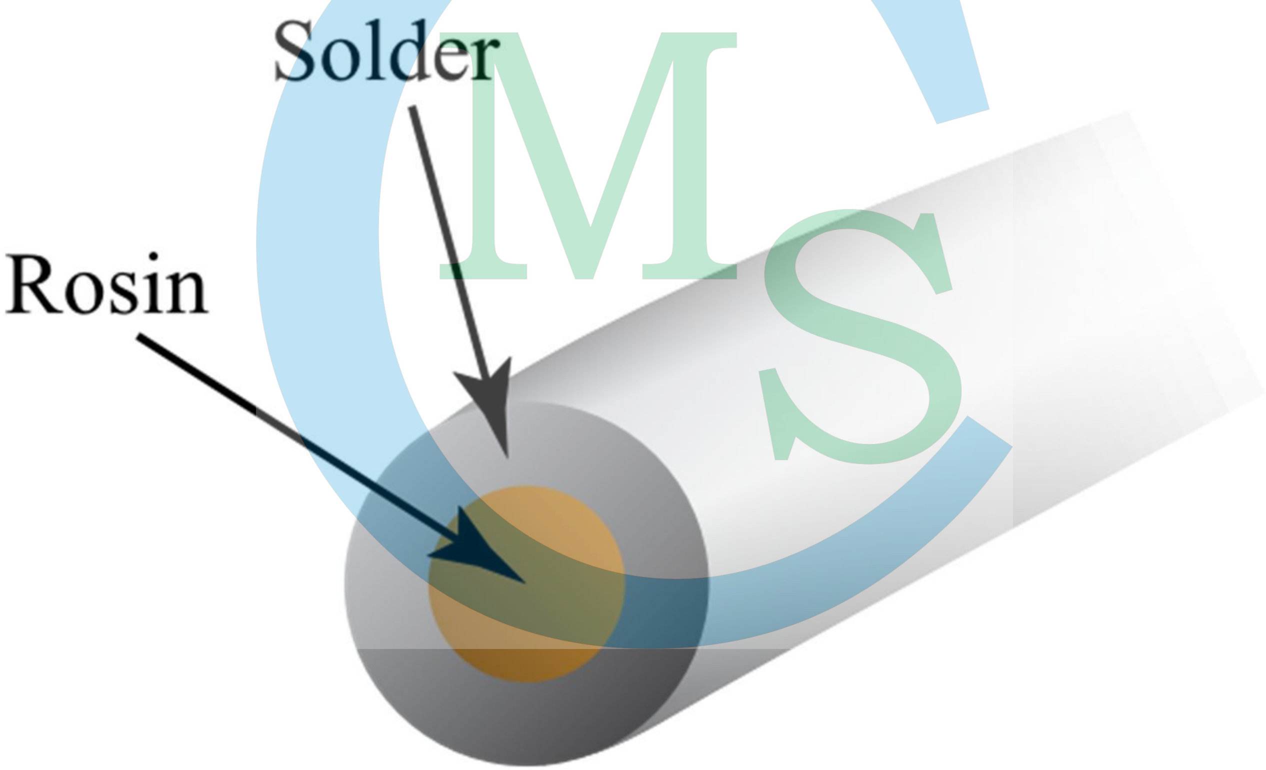
Flux

- ***DO NOT,*** under any circumstances, use acid flux or acid-core solder for electric or electronics work!
- Clean up any excess or burned rosin flux using a scrub brush (like an old toothbrush) and some 99% isopropyl alcohol (IPA)
- Flush the area with some clean IPA after scrubbing it, and blot or air dry the whole thing afterwards

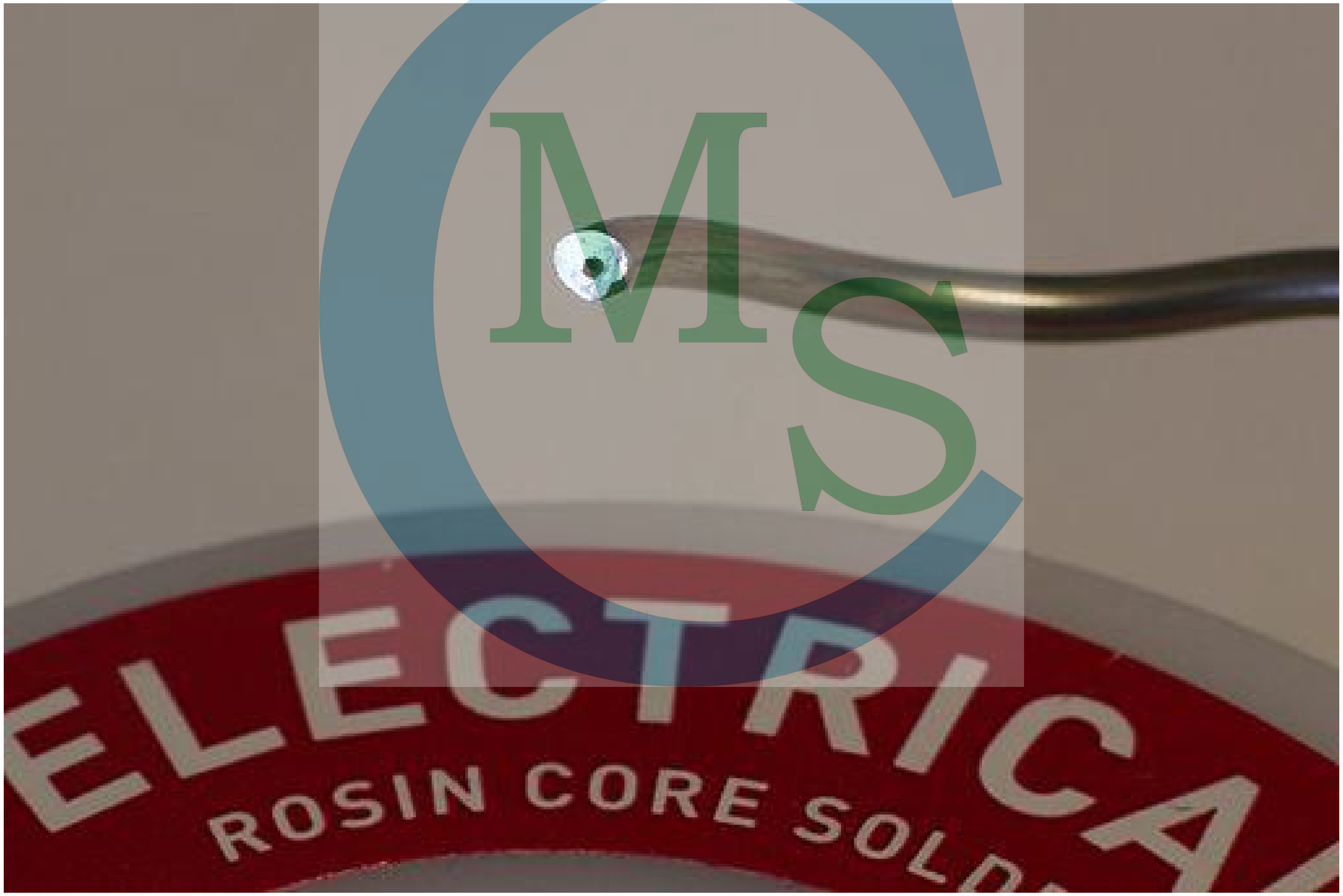
Flux

- Different solder alloys will require different amounts of flux, stated as a percentage of the total volume of the solder and flux mix, *e.g.,* 2%, or 5%, or 7%, *etc.*
  - The core diameter of a wire solder is based upon this flux percentage requirement – different alloys of the same diameter will have different core diameters
  - The flux volume is proportional to the wire diameter and is correct for the wire alloy used

Rosin Core Solder



Rosin Core Solder

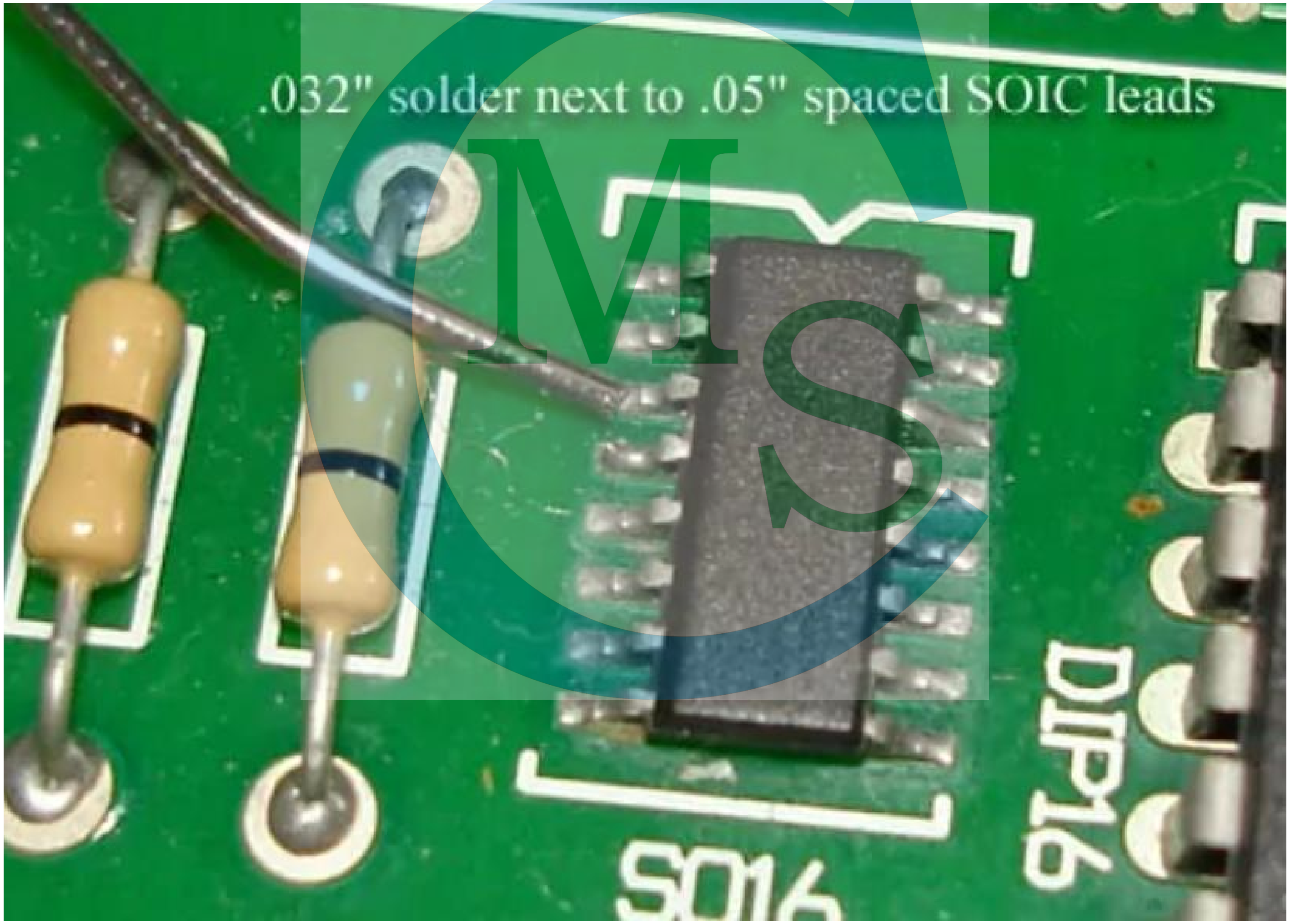


Solder Diameters

- Electronics solder wire will be thin, from 1.5mm (0.060”) down to 0.5mm (0.020”), or even less
- Even the thinnest solder wire can and should be rosin-cored for electronics work
- Keep a variety of solder diameters on hand for specific work or task needs
- Size the wire used to the joint being made

Wire Solder Size Comparison

0.032” Solder *vs* 0.05” Pitch



Successful Soldering

- Main points for successful soldering:
  - Keep soldering iron tip clean and tinned
  - Use proper temperature
    - DO NOT overheat the work
  - Use an appropriate tip size for the job at hand
  - Use plenty of flux, especially when working with SMD's
  - Use heat sinks as required, especially when working with semiconductor devices
  - Work under bright light conditions

Tip Cleanliness

- Keep a damp sponge at hand for tip wiping
- Keep some Chore-Boy™ pot-scrubber material at hand for tip scrubbing
- DO NOT use files or other abrasives on the tip of the soldering iron at any time
- Tin the tip before first use and periodically while using it
- Remove oxidation and carbon by wiping or by scrubbing with materials as above

Iron Practices

- Keep the tip or tip holder tight in the iron
  - Loose tips will not heat properly and cannot transfer heat correctly
  - Dirty tips act the same as loose tips
- DO NOT put excessive side force on the tip
- Turn the iron off when not in use
- Clean the inside of tubular tips periodically to aid in proper heat transfer from the heating element inside the tip

Iron Practices

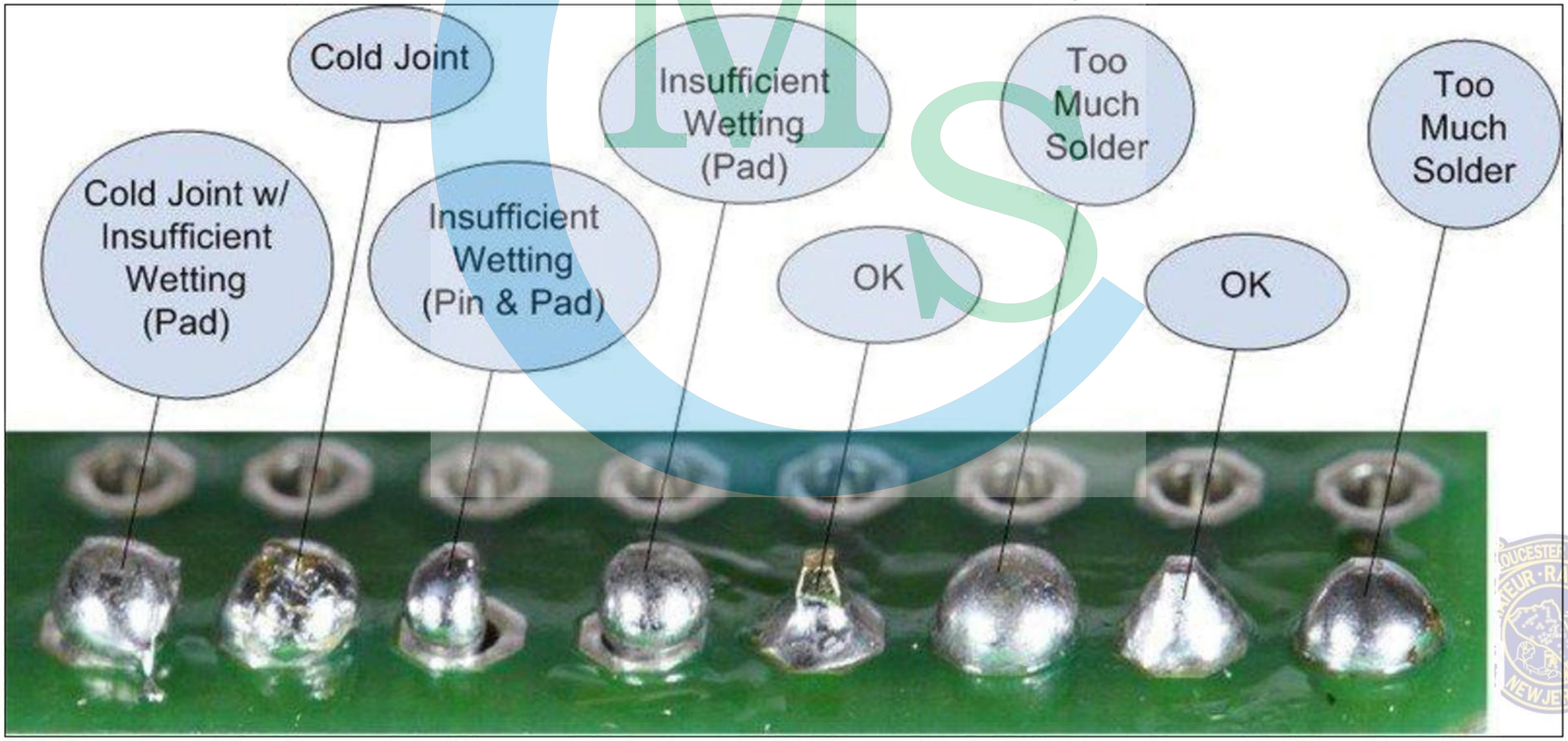
- Place the iron against one side of the joint
- Bring the solder into contact with the opposite side of the joint
- Allow the solder to be drawn to the heat source by natural action
- If joint is in open air, heat from underneath and apply solder from above

Iron Practices

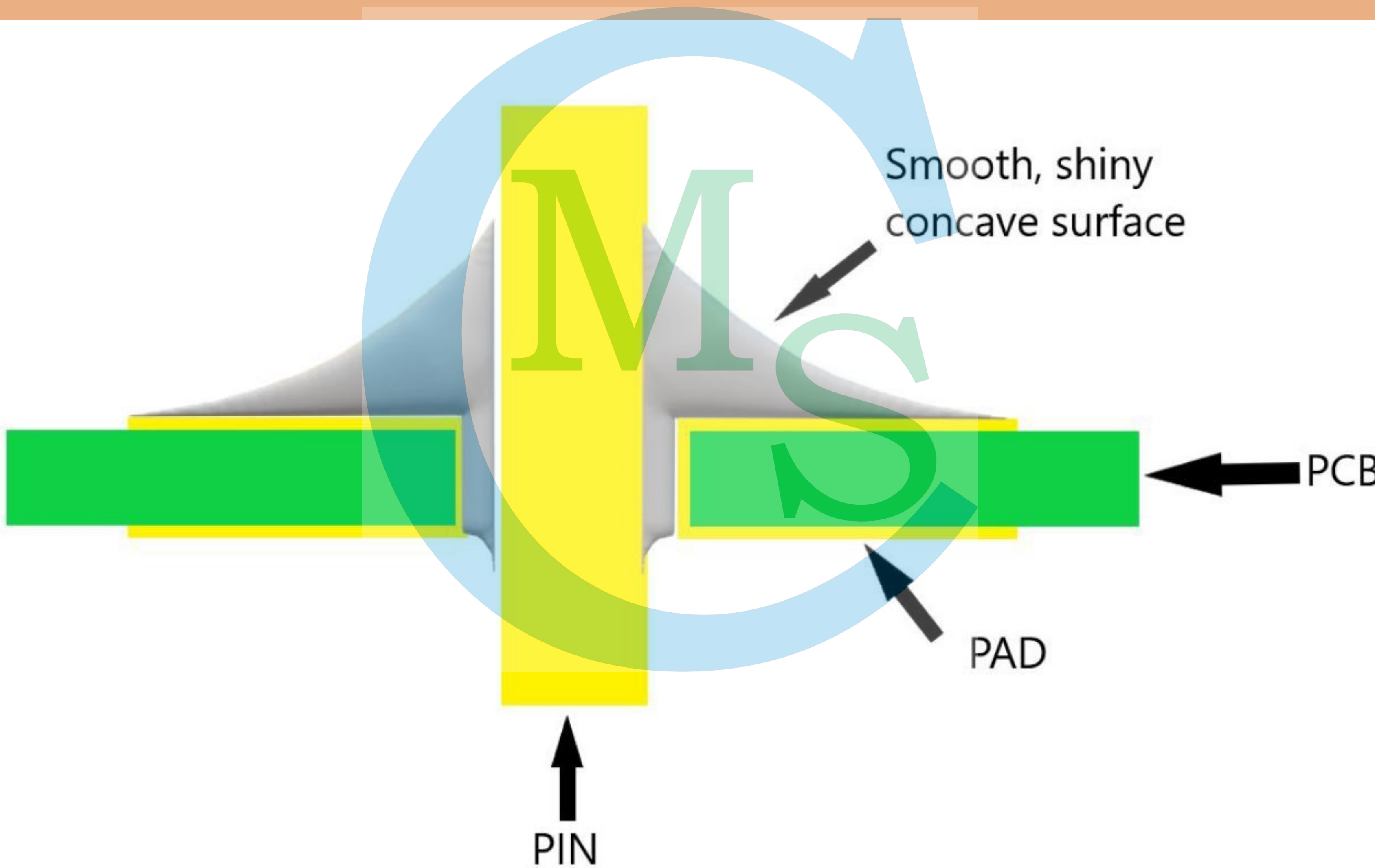
- Use the body of the tip rather than the point of the tip to heat the joint
  - Greater surface area in contact yields quicker heating of the joint
- Chisel tips are often preferred over needle tips for general soldering work
  - Chisel tips can be turned either way to widen or narrow the contact area

Solder Joint Compasrisons

- Examples of various soldered joints are shown below – good and bad!

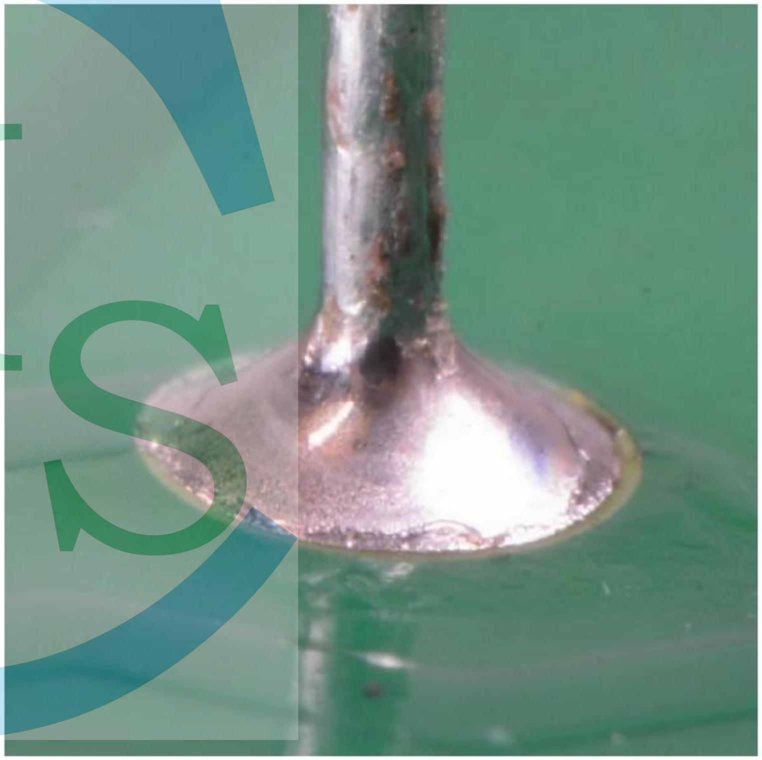


Anatomy of a Good THT Joint

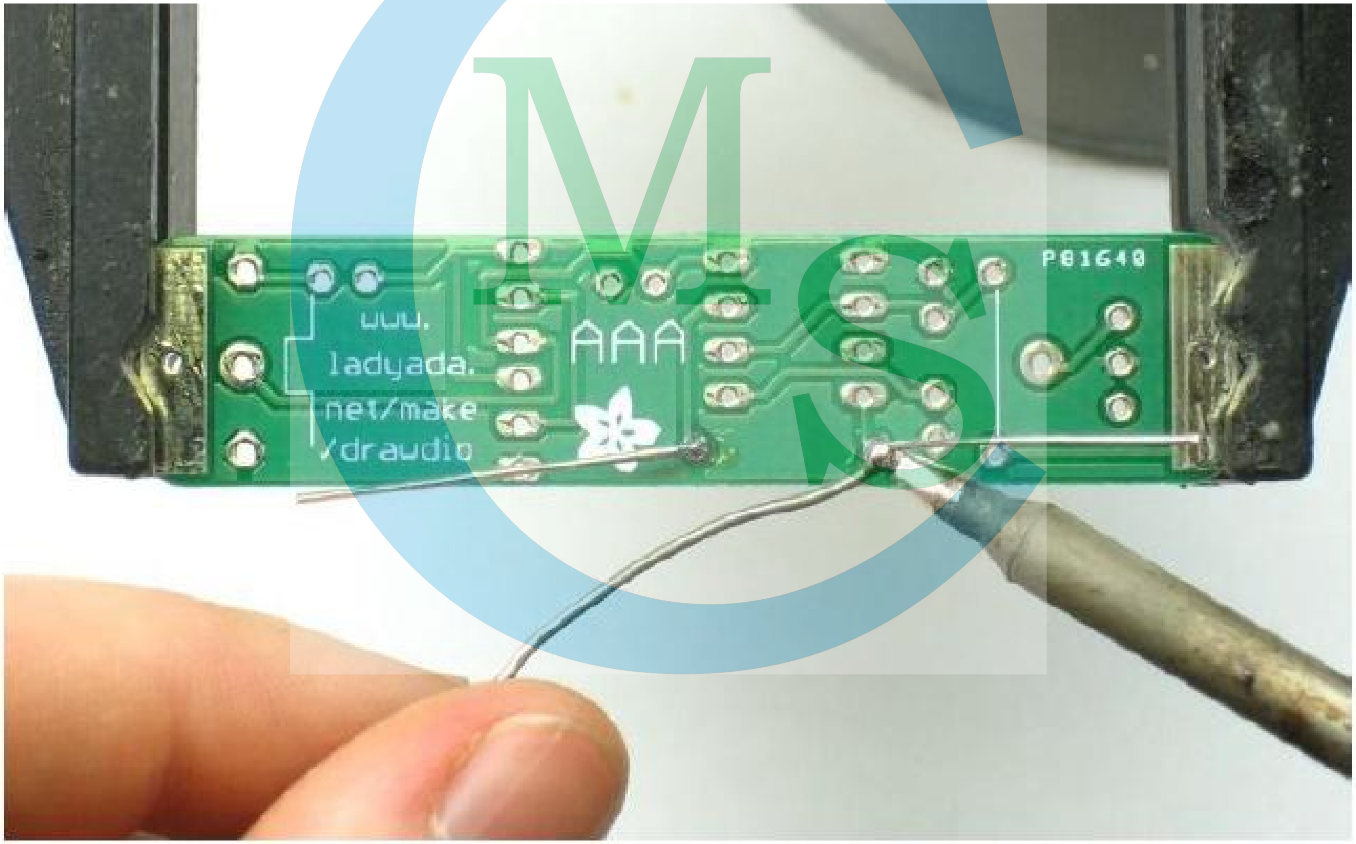


Solder Joint Appearance

- Note the conical shape of the joint…
  - Smooth slopes / no lips
  - Seamless change from solder mound to body of component lead
  - Seamless change from solder mound to printed circuit board (PCB) surface



Proper Iron Technique



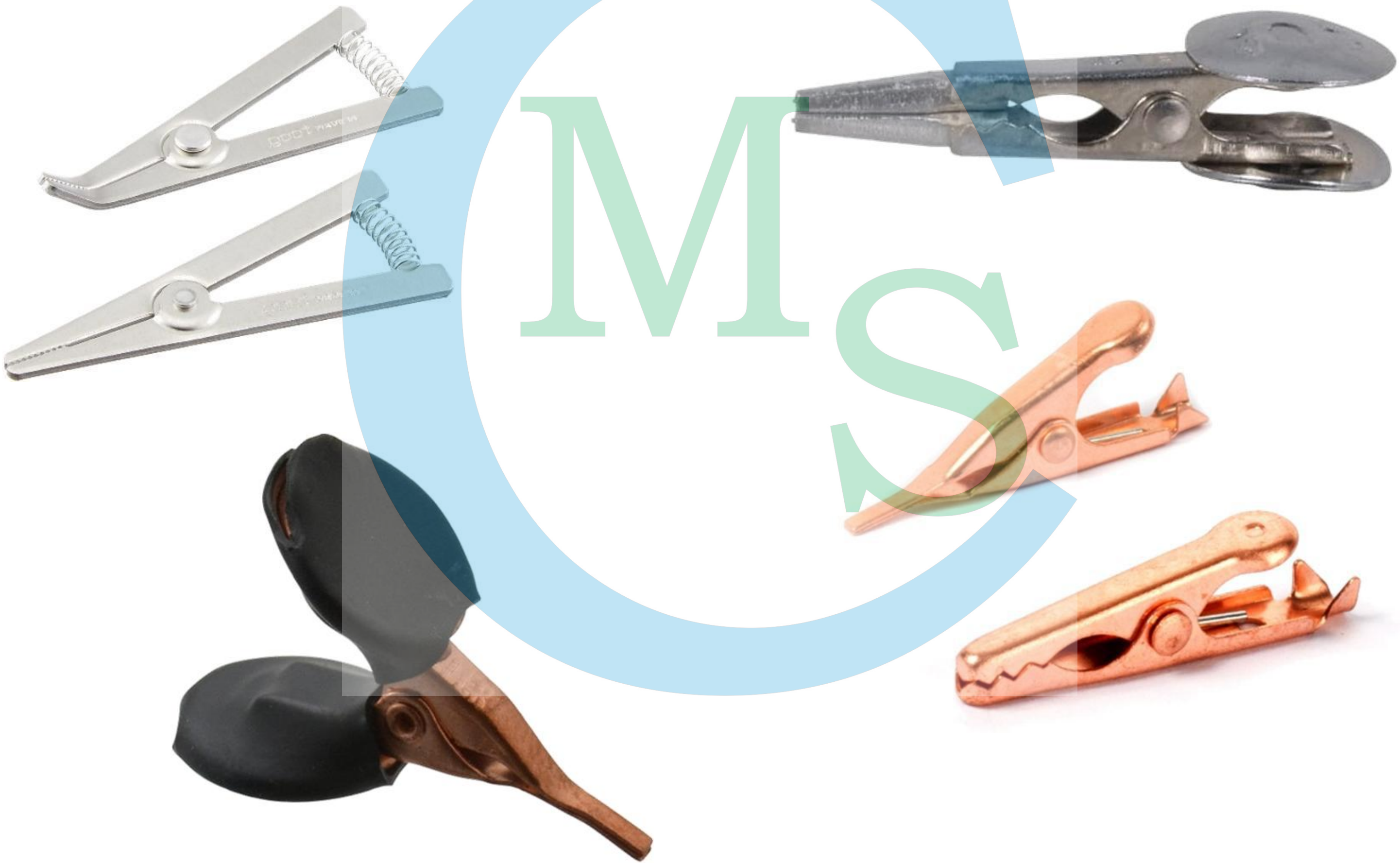
Some More Tips

- Secure the circuit board against movement… you don't want to be chasing the board around the benchtop
- Start with a good mechanical joint… this is especially important in "dead bug" or point-to-point wiring
- When lap joints are necessary, be sure to tin both elements of the joint first

Semiconductors

- Keep iron dwell time to the absolute minimum possible
- Use a heat sink between the heated point and the component body, for example…
  - Alligator clips, especially copper ones
  - Hemostat
  - Needle-nose pliers with a rubber band on the handle
  - Purpose-made heat sink

Heat Sink Types



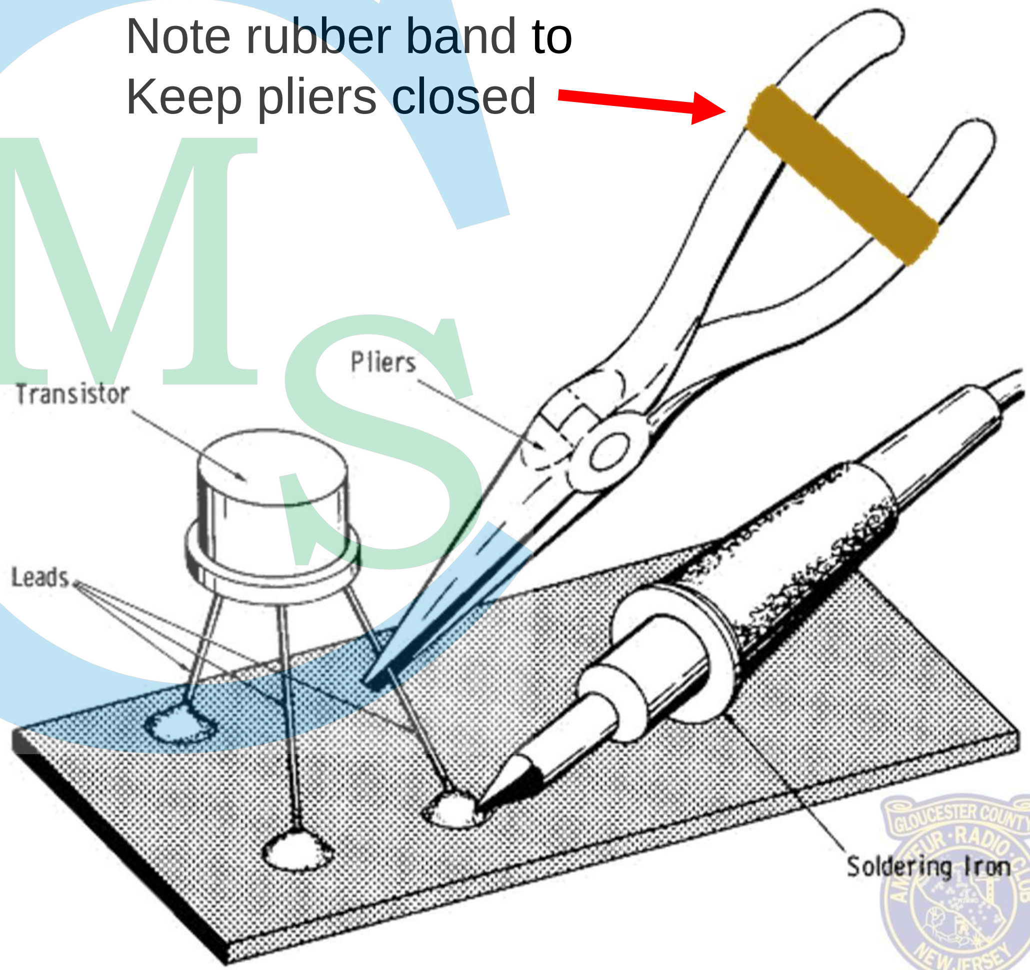
Hemostat As A Heatsink

- A hemostat will clamp onto the lead and will latch in its closed position, so making it a great heat sink

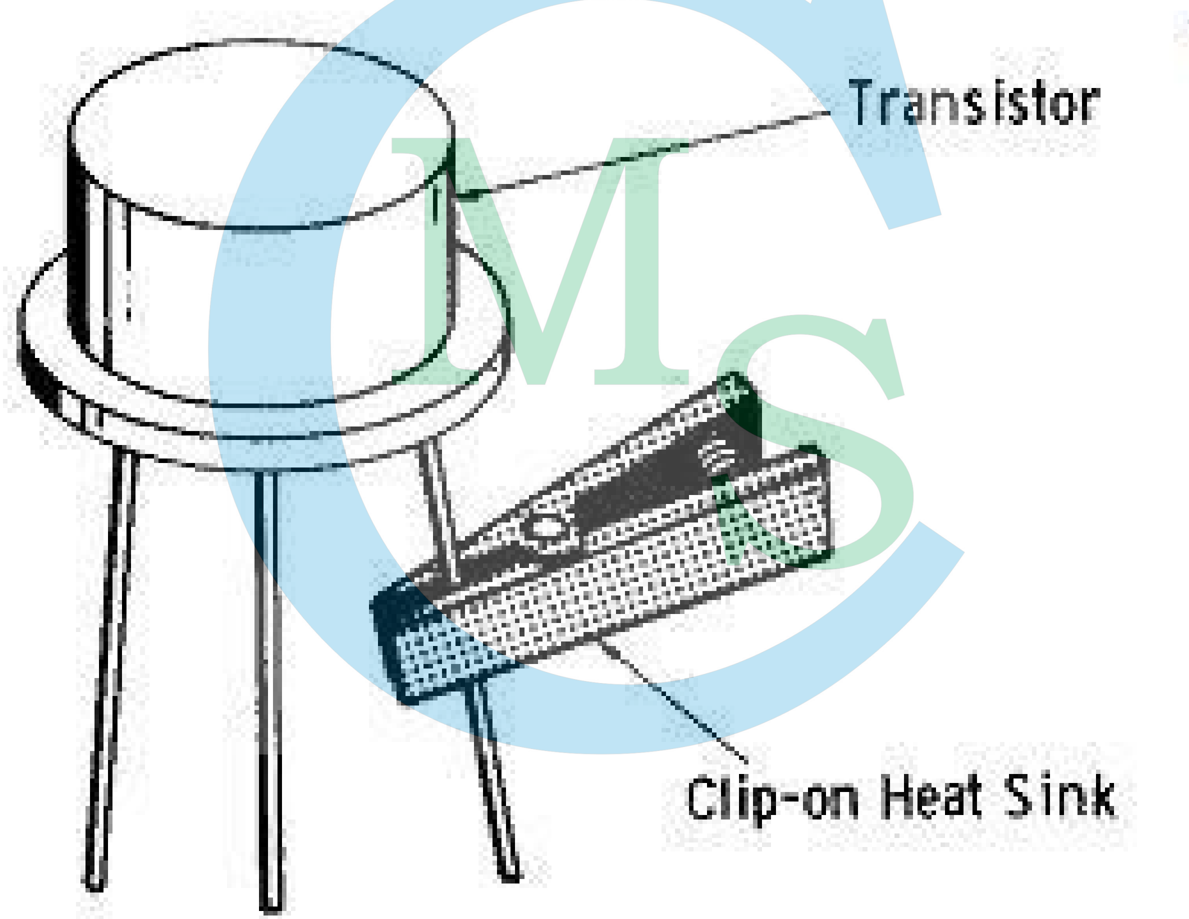
Heat Sink Use

- Attach the heat sink between the solder point and the component body
- Use heat sink on each component lead in turn

Note rubber band to
Keep pliers closed



Heat Sink Placement



Some More Tips

- Bend through-hole component leads apart slightly to keep the component from falling out of the board when the board is inverted for soldering
- When possible, tack the component in place from top side of the board, and then finish the job from the foil side of the board

Special Cases

- To solder a pin header or IC socket, tape can be used to hold the part in place for soldering
- Tack one lead in place, adjust the component dress, and then finish the soldering job
- To solder a screw-secured component, securely tighten the screw first, and then solder the leads.
  - Reversing the sequence will cause damage to the joints and/or to the board

Special Cases

- When a component has pins and ground plane attachments such as D-sub connectors have, solder all of the ground plane attachments first, then solder the circuit leads
- When installing toroids, twist the leads together under the board to hold the toroid in place, and then solder and cut the leads apart by trimming the lead length

Special Cases

- If a single *cracked* solder joint is found on a board, it is probably best to re-flow all of the joints on the board
- If a single *cold joint* is found on a board, it is generally acceptable to re-flow that one single joint, but be sure to inspect all of the remaining joints for proper condition and appearance

Re-flow as Repair

- Repair of a solder joint by re-heating the joint and allowing it to cool properly is known as *re-flowing* a joint
- Re-flow work can be done using an iron, using an oven, or by using hot air or hot gas
- Flux should *always* be applied to any joint undergoing a re-flow repair

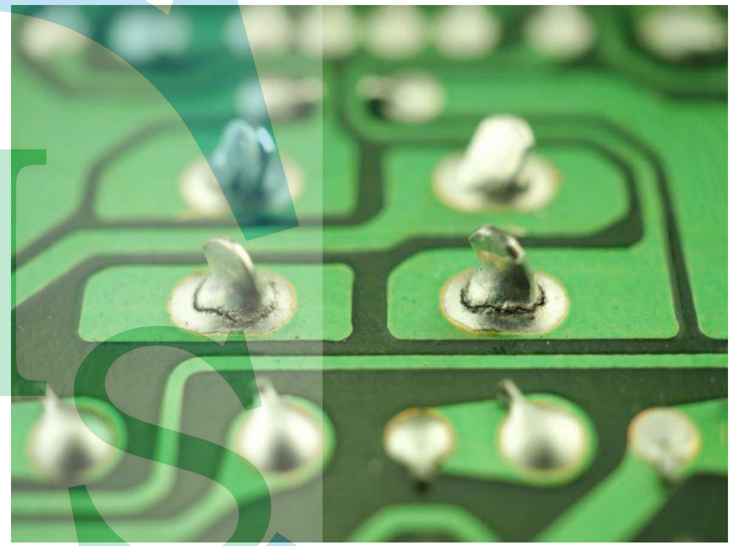
Re-flowing a Solder Joint

1. Apply plenty of rosin flux to the joint
2. Apply heat to the joint until existing solder melts – two to three seconds
3. Add more solder if needed
4. Remove heat and allow the joint to cool
5. Inspect for joint adequacy
6. Repeat as necessary

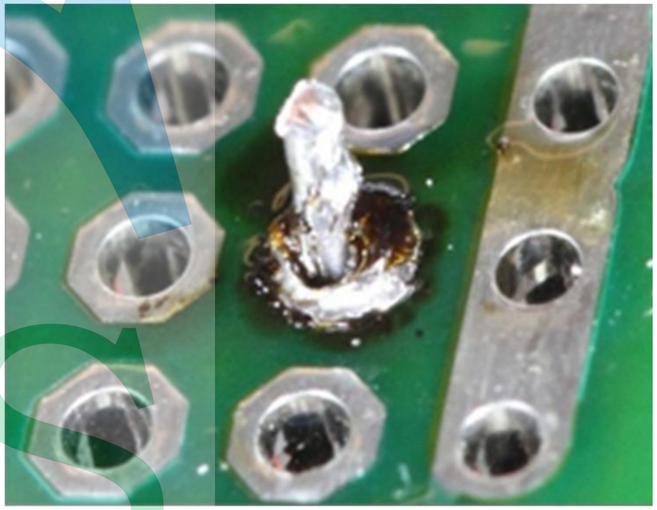
Cold Joints

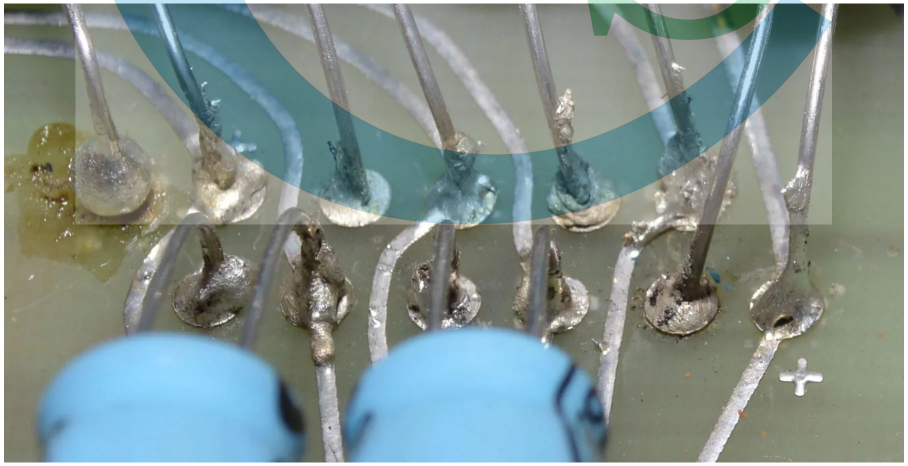
- A joint with a dull and lumpy appearance is called a *cold joint*
- Causes…
  - Inadequate heating
  - Inadequate solder applied
  - Movement of joint while cooling
  - Insufficient wetting
  - Insufficient flux

Cold Joint Images



Cold Joint Images





Cold Joint Prevention

- Heat the pad and the component adequately
- Use sufficient flux
- Apply a sufficient amount of solder
- Allow the joint to cool naturally…
  - DO NOT blow on the joint
  - DO NOT move the component or allow the component to move

Too Much Heat

- Too much heat can be just as bad as too little heat…
  - Excessive heat can damage the components being soldered
  - Excessive heat can crystallize the joint
  - Excessive heat can cause traces and pads to lift off the printed circuit board
  - Excessive heat can damage the printed circuit board substrate

Reworking Lead-Free Joints

- Lead-free joints have a high early failure rate due to the nature of the materials used
- Failed joints can be difficult to locate
- Re-flowing Pb-free joints will require more heat than will leaded solder joints
  - Pb-free solder may have melting points as much as 200°C higher than Pb solder
- Pb-free joints have a duller grey appearance as compared to leaded joints

Lead-free Joints

- Pb-free joints will have a grainy, dull and lumpy appearance similar to that of a cold joint

63/37 Solder in air

SAC Solder in air*

* SAC solder is Pb-free Sn/Ag/Cu alloy solder

Differentiation

- To help determine if a joint is a cold joint or not, look at the remainder of the joints in the device
- If ***all*** of the joints have a dull grey appearance, the device is probably built with Pb-free solder.
- If a device is declared to be *RoHS-compliant,* the device was built with Pb-free solder

RoHS Directive

- RoHS is an abbreviation for the *Restriction of Hazardous Substances Directive*, an EU legislative act that limits the use of certain hazardous substances, including lead, in most consumer-grade products
  - Adopted in February 2003 and initially effective on 1 July 2006, RoHS places limits on the use of:
    - Lead (Pb)
    - Mercury (Hg)
    - Cadmium (Cd)
    - Hexavalent chromium (Cr6+)
    - Polybrominated biphenyls (PBB)
    - Polybrominated diphenyl ether (PBDE)
    - Bis(2-ethylhexyl) phthalate (DEHP)
    - Butyl benzyl phthalate (BBP)
    - Dibutyl phthalate (DBP)
    - Diisobutyl phthalate (DIBP)

Desoldering PB-free Joints

- Due to their higher melting points, many Pb-free joints will be very difficult to de-solder using conventional methods
- One method that I have used is to re-flow the joint first, using standard 63/37 Sn/Pb solder, and then to de-solder the joint, repeating the re-flow and desolder steps as necessary to get a clean result

Moving on to SMD

- Soldering SMD components requires a somewhat different skill set
  - Good iron habits and skills are imperative
  - Multiple methods are possible, including hot air, oven and iron work
  - Different variations of standard solder may be used, including wire solder and paste solder
  - Stencils can be used to aid in the placement of solder paste
  - Light and magnification are great aids

Wave Soldering

- Before we talk too much about SMD components, we should mention *wave soldering*
- Wave soldering is generally used in high-production facilities for the automated soldering of through-hole components to a PCB, but *can* be used for SMD components
- SMD components must be glued into place before wave soldering can be done

Wave Soldering

- In wave soldering, a PCB stuffed with its components is placed into a pan of molten solder, which is then caused to flow over the board via a wave action (thus the name)
- Solder adheres to those places that have been properly prepared and does not adhere to those that have been properly protected (solder mask, *etc.*)
- Wave soldered work can often be identified by the absolute uniformity of the solder joints

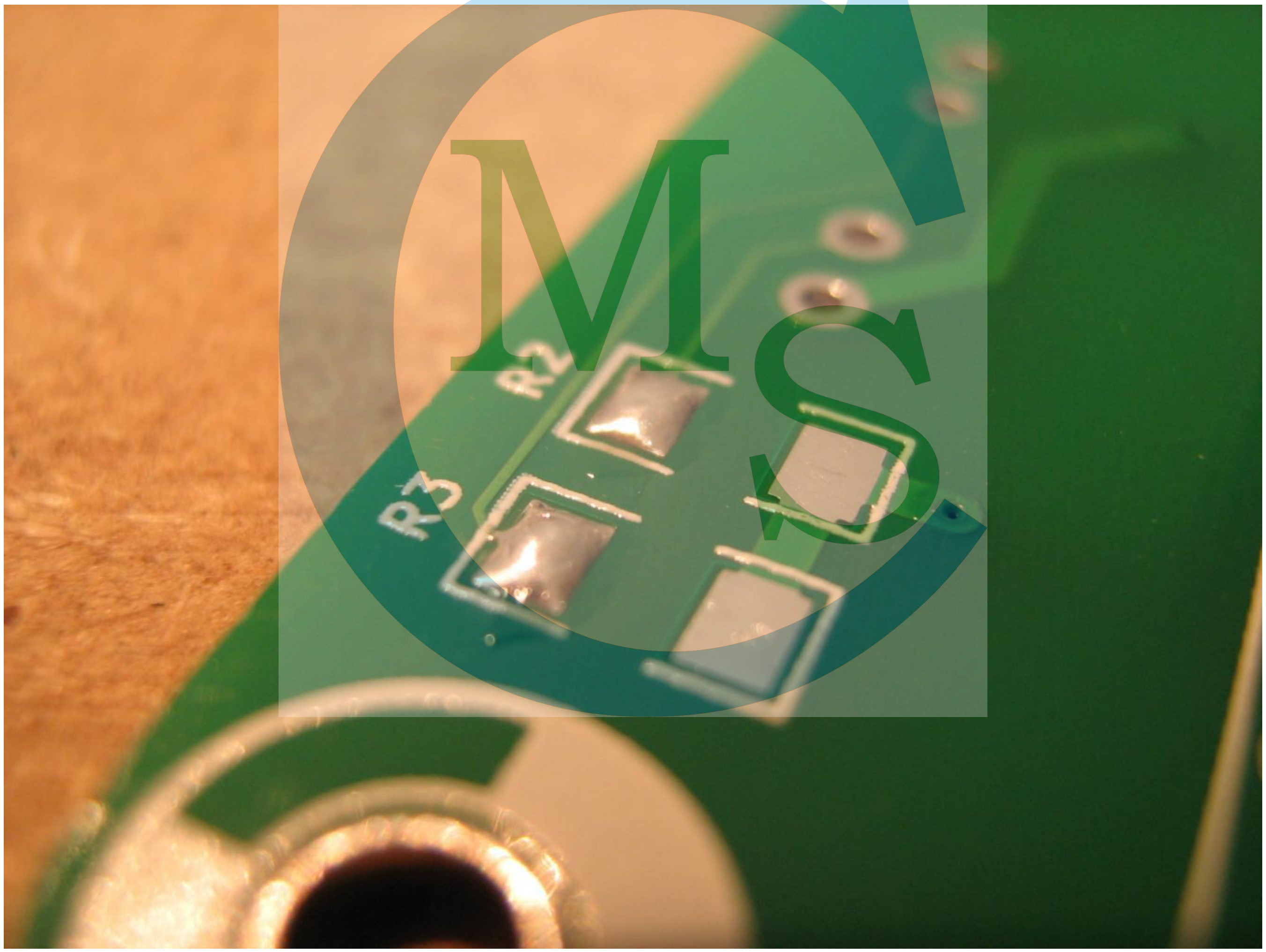
SMD Soldering Methods

- Apart from the wave soldering already mentioned, SMD components can be soldered by hot air, hot gas, oven heating, or iron soldering
- Iron soldering and hot air are most widely used methods for hobbyists
  - An old toaster-oven can be a great re-flow oven for smaller boards that can fit inside the oven
- While paste solder can be used for either method, its use is generally required for the hot air soldering method

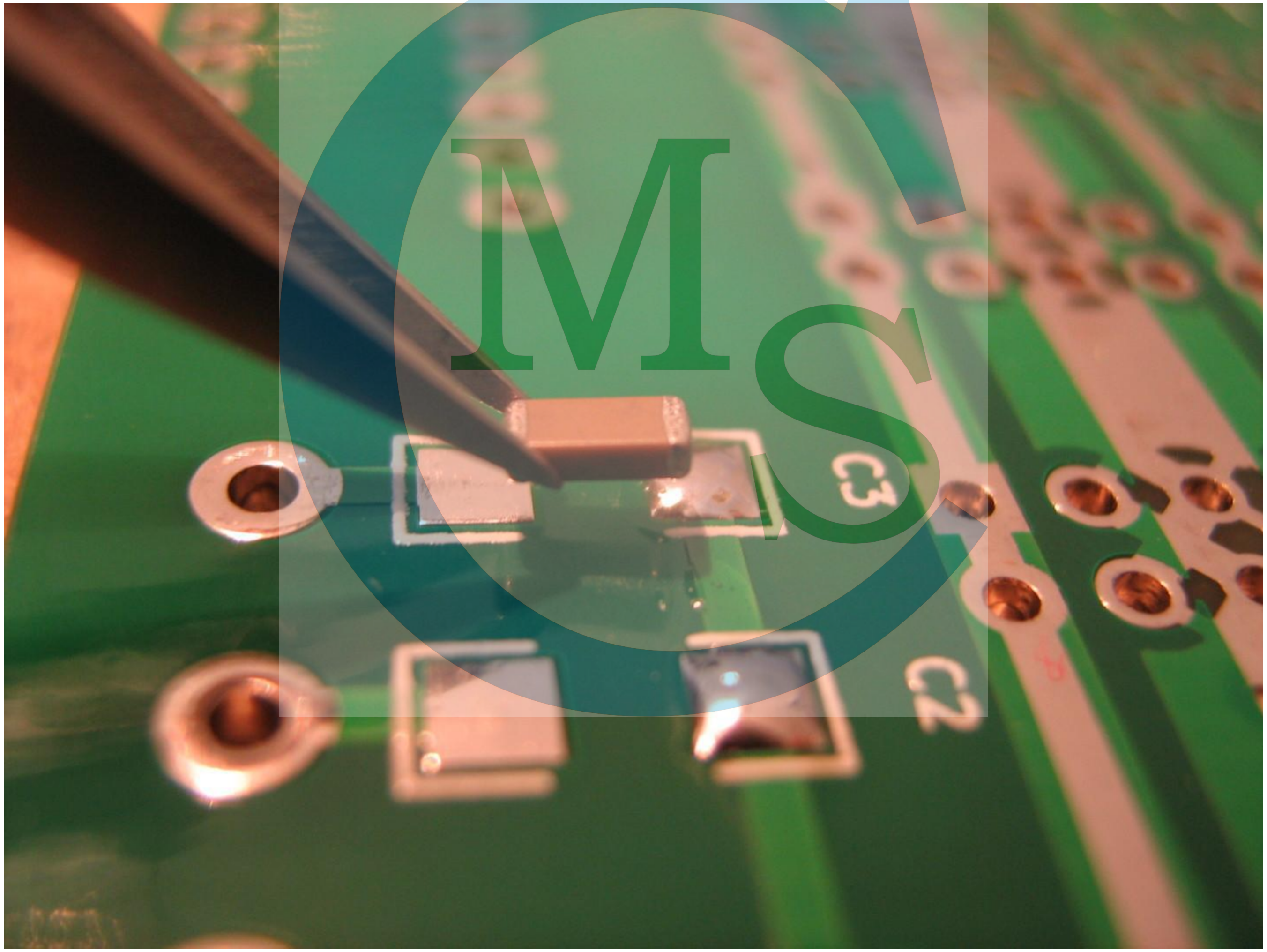
Iron Soldering with SMD

1. Begin by tinning at least one of the pads to which the device will be installed
2. Position the device onto its pads using tweezers
3. Hold the device in place with the tweezer
4. Heat the tinned joint to tack the component in place
5. Solder the remaining pad(s)
6. Return to the tacked pad and solder it

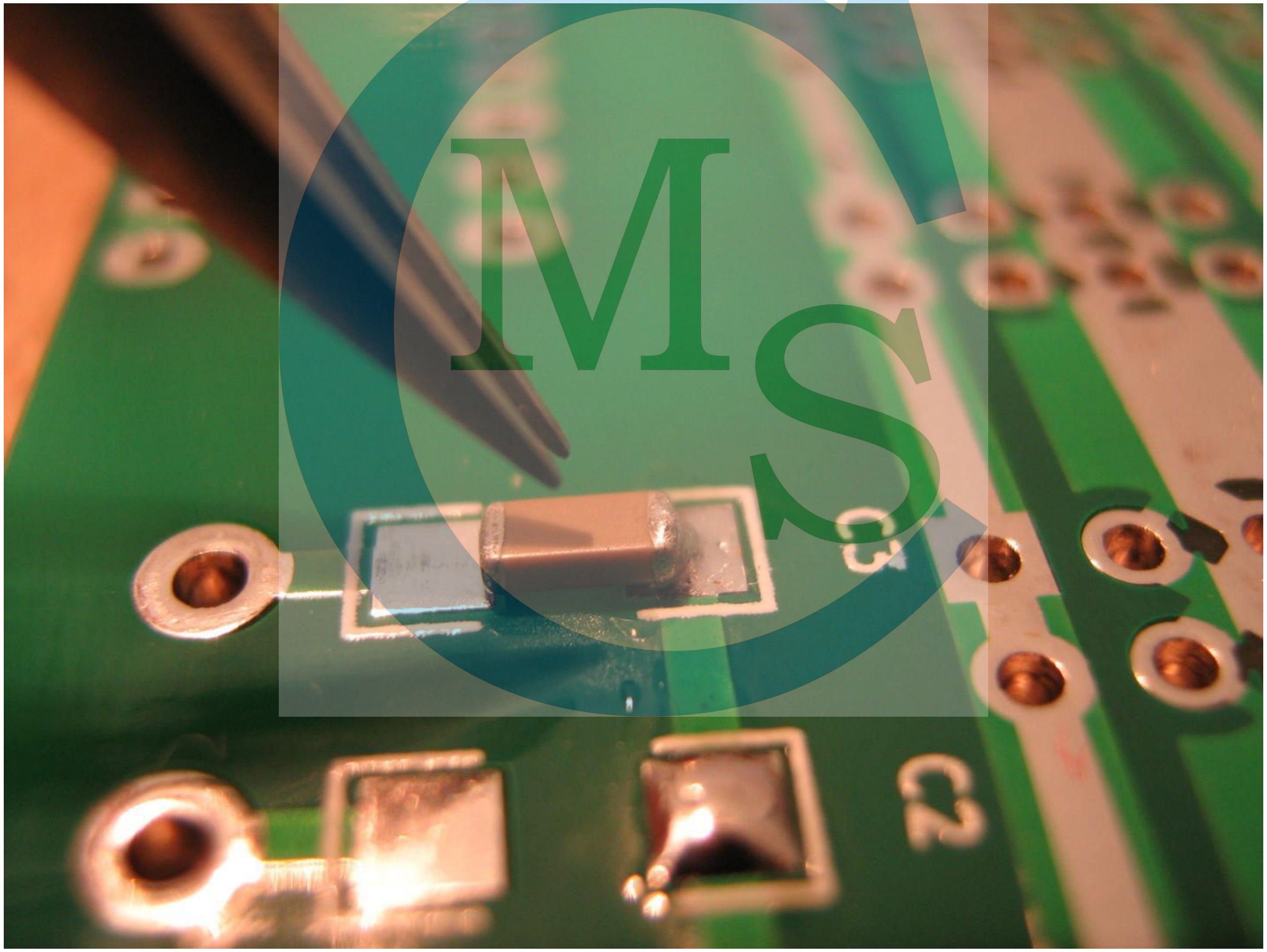
Tin One Pad



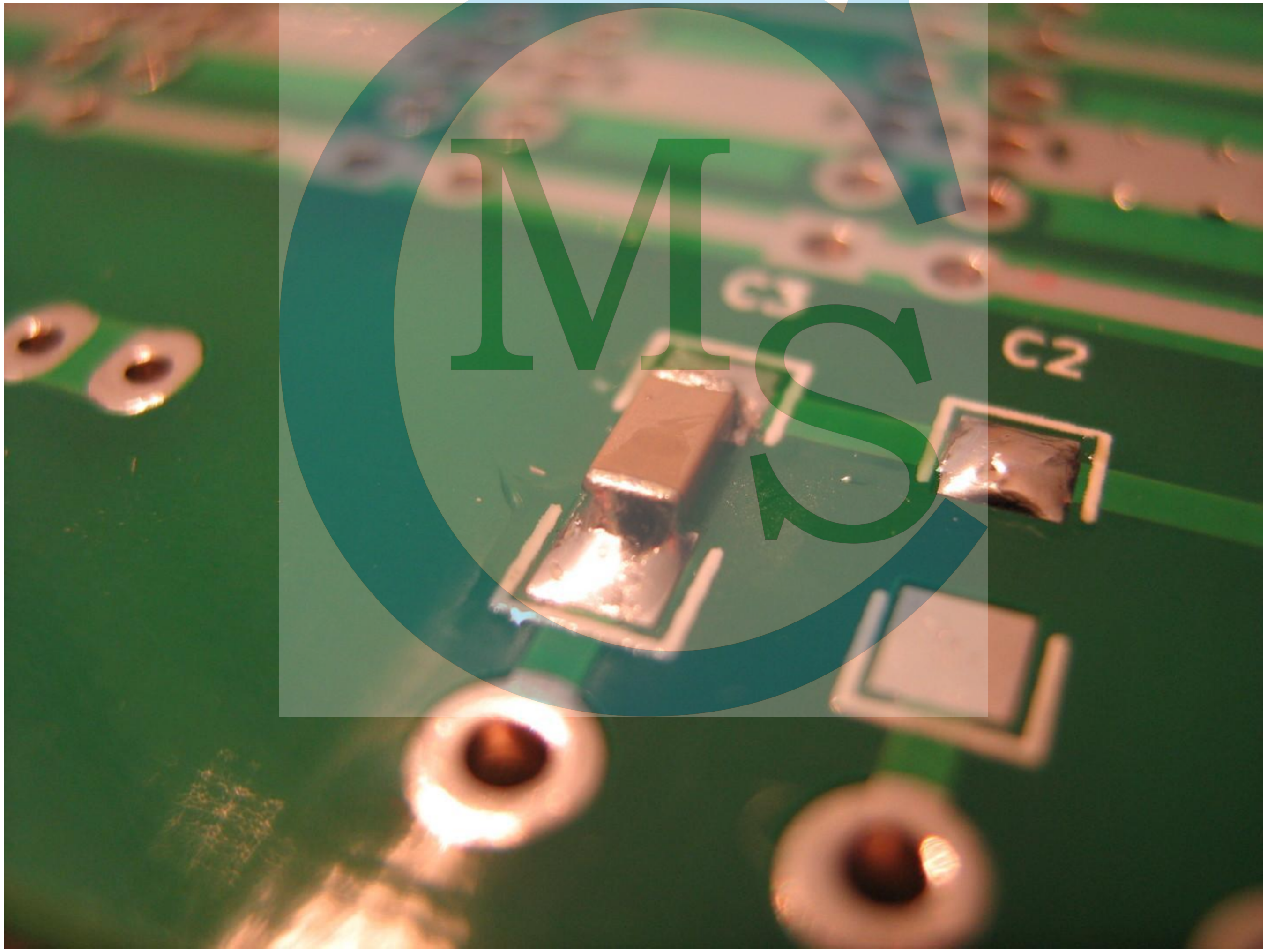
Place the Component



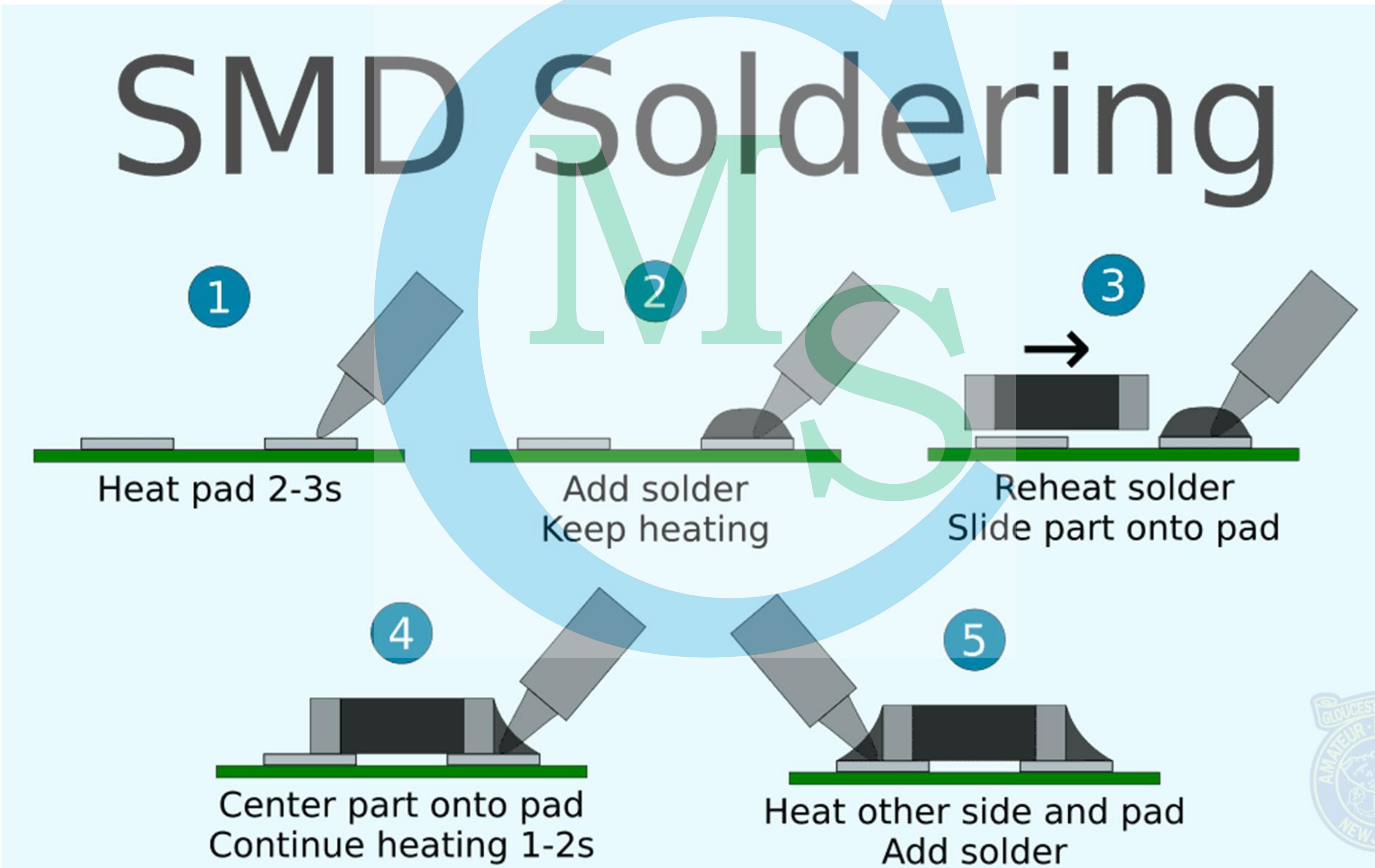
Tack the Tinned Pad



Finish the Job



An Alternative Method

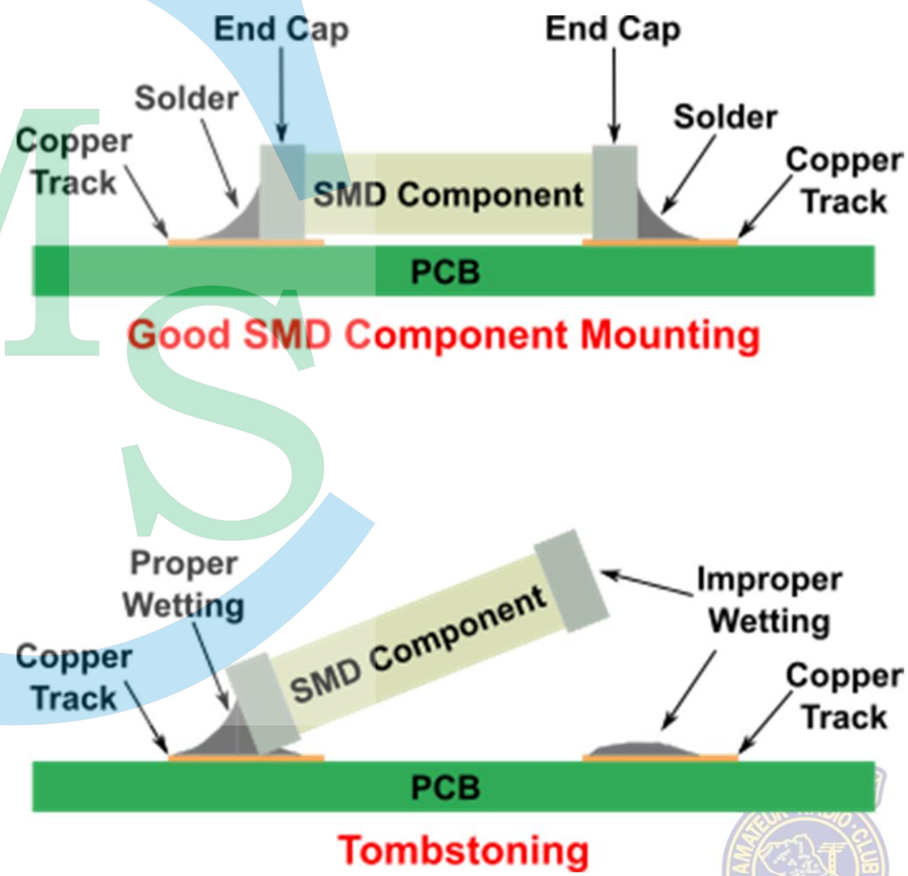


Tombstoning

- *Tombstoning* occurs when one end of the SMD component lifts up off the board as the opposite end is being soldered
- This can be avoided by keeping some downward pressure on the component while tacking the first pad
- If tombstoning occurs, re-heat the joint to lay the component down on the board

Proper SMD Joint Appearance

- A proper fillet should be present at each pad
- Tombstoning can be avoided by proper pressure and adequate wetting



Solder Paste

- *Solder paste* is essentially powdered solder suspended in a flux binder base
- The tackiness of the flux binder holds the components in place until the soldering reflow process melts the solder, forming the joints
- Flux binder may be:
  - Rosin flux – the conventional type
  - Water-soluble flux – uses organics in glycol base
  - No-Clean flux – leaves very little residue behind

Using Solder Paste

- High-quality solder paste will stay where it is placed on the board – will not run
- Stencils will help in the proper application of solder paste to the PCB…
  - …controls location of paste applied
  - …controls thickness of paste layer
- When paste is applied with a stencil, the paste is spread across the stencil using a squeegee

Soldering Process

1. Clean the PCB properly
2. Apply the solder paste to the PCB
3. Place the components in their proper locations, noting the polarity of various components as required
4. Apply the heat required to melt the solder and cause it to flow
5. Maintain the heat until all solder has flowed and all joints are made
6. Allow PCB to cool naturally

Hot Air Soldering

- When using hot air to solder SMD components, reduce the air flow to a level where the components will not be blown around on the board
  - Some adhesion to the solder paste will help to keep the components in place
  - I like to press each component down into the paste instead of simply placing them on top of the paste
- Most better solder stations will allow independent control of the temperature and the airflow
  - Experiment until you get it right!

Soldering SMD IC's

1. Apply plenty of flux to the IC footprint on the board
2. Solder all leads to their pads, not worrying about solder bridges
3. Use fluxed solder wick to remove the excess solder and the bridges, working from the body of the IC outward along the leads
4. Clean up the excess flux with 99% IPA

Desoldering SMD Components

- SMD components are easy desoldered with an iron and solder wick
- Often, they can simply be heated and wiped off the board, especially resistors and capacitors
- DO NOT attempt to move the component until all solder has melted, as pad damage could result otherwise

General Desoldering Tips

- When desoldering a multi-pin component, begin by soldering a short length of heavy (10AWG or 12AWG) solid wire across all of the pins, flooding the area with solder
- Next, heat the large wire and the solder mass until it all melts, and the device will just about drop out
- If the pins are a snug fit in their holes, some help may be needed once the solder is melted

General Desoldering Tips

- Large-gauge wire soldered across the rows of pins to remove a large component with multiple pins from a PCB

General Desoldering Tips

- When desoldering through-hole components in plated through-holes, work from under the board, so that the desoldering heat rises up into the holes
- Once the solder is drawn out of the holes, the device may be wiggled loose with the heat still applied
- Keep wiggling the device until it cools and does not bond back to the board
  - If the device bonds back to the board, free solder still remains in the holes – repeat the vacuum process

General Desoldering Tips

- IC's and IC sockets can be removed using the solid wire tip, but using slightly lighter wire instead of the AWG10 or AWG12 wire
  - AWG 16 or AWG14 wire should suffice
  - Solder the wire to both rows of pins of the DIP device, and then heat the whole thing for rapid desoldering
  - Such devices will fall out when the solder is melted
- In all cases, clean the board with solder wick and the vacuum gun afterwards, being sure to clear the holes as well as the board surface
  - Finish the clean-up job with 99% IPA

What NOT To Do

- A method that is discussed at various online sites is to used compressed or canned air to aid in desoldering
- In this method, the solder is melted using a normal iron, and then the molten solder is blown away with the compressed air
- Does *anyone* see anything wrong with doing this?
  - Molten solder goes flying everywhere (burns, shorts?)
  - Solder still remains in the holes, especially if they are through-plated holes
  - There are folks online who will light gaseous bodily emissions on fire, but I wouldn't do that, either!

Instead…

- Hot air from a hot air soldering or rework station can easily be used to desolder components, including DIP devices like IC’s and IC sockets
- Work from above the inverted board, and apply the heat carefully to the device to be removed, keeping the air nozzle moving to melt all of the solder retaining the component
- Once heated enough, the component will often fall right out, and the hot air will often also clear the holes of solder
- Components with bent-over leads will need some help by straightening the leads enough to allow the component to fall out

Conclusions

- Get the best solder equipment you can afford, planning for the future
- Use high-quality solder and flux
- Use leaded solder when and where possible for best results
- Use proper heat levels and avoid overheating components and boards
- ***SAFETY FIRST!***

Questions?