Solutions for Selective Soldering of High Thermal Mass and Fine-Pitch Components

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Abstract

The selective soldering process has evolved to become a standard production process within the electronics assembly industry, and now accommodates a wide variety of through-hole component formats in numerous applications. Most through-hole components can be easily soldered with the selective soldering process without difficulty, however some types of challenging components require additional attention to ensure optimum quality control is maintained.

Several high thermal mass components can place demands on the selective soldering process, while the use of specialized solder fixtures and/or pallets often places an additional thermal demand on the preheating process. Fine-pitch through-hole components and connectors place a different set of demands on the selective soldering process and typically require special attention to lead projection and traverse speed to minimize bridging between adjacent pins.

Dual in-line memory module (DIMM) connectors, compact peripheral component interface (cPCI) connectors, coax connectors and other high thermal mass components as well as fine-pitch micro-connectors, can present challenges when soldered into backplanes or multilayer printed circuit board assemblies. Adding to this challenge, compact peripheral component interface connectors can present additional solderability issues due to their beryllium copper termination pins.

Key Terms: Selective soldering, drop-jet fluxing, sustained preheating, flux migration, adjacent clearance, lead-to-hole aspect ratio, lead projection, thermal reliefs, gold embrittlement, solderability testing

Choosing a Flux

Liquid fluxes for selective soldering are available in many types including alcohol-based fluxes, water-soluble fluxes, rosin-based fluxes, low pH fluxes and fluxes with high solids content. The choice of a particular type of flux for the selective soldering process is generally specified for the end application of the product and is critical with regard to the resulting solder joint integrity.

Flux chemistry selection criteria should be based on the solderability of the base metal surfaces being soldered. Base metals that are easy to solder including platinum gold, copper, tin-silver or palladium silver can typically be soldered with either a no-clean flux, a non-activated rosin flux or a mildly activated rosin flux. Base metals that are less easy to solder such as beryllium copper generally require either a fully activated rosin flux, a water-soluble organic flux or a water-soluble inorganic flux, with these latter flux types, post-soldering cleaning of the board assembly is required in most cases.

Metal Surfaces	Solderability	No Clean Fluxes	Non-Acivated Rosin Fluxes	Mildly Activated Rosin Fluxes	Fully Activated Rosin Fluxes	Oraganic Fluxes Water Soluble	Inorganic Fluxes Water Soluble
Platinum Gold Copper Tin Solder Palladium Silver	Easy to Solder	958 959	135	186 186-18	1544 1588	2235 1429 2331-ZX	Not Recommended for Electrical Soldering
Nickel Brass	Less Easy to Solder						715
Cadmium Lead Bronze							
Rhodium Beryllium Copper							
Nickel-Iron Kovarl	Difficult to Solder						
Zinc Mild Steel Chromium Inconel Monel Stainless Stee	Very Difficult To Solder						817 3350

Figure 1. Metal solderability chart and flux selection guide (Kester)

It is widely known that liquid flux must be present and active in order to clean and protect solderable surfaces before the surfaces come in contact with liquidous solder flowing from a selective soldering nozzle. Since the function of a liquid flux is to raise the energy level and promote wetting of the solderable surfaces, proper thermal activation is essential to dry the flux vehicle and activate the flux solids. High melting point solder alloys require robust fluxes capable of surviving higher preheating temperatures required for these specialty high melting point alloys.

Flux migration often occurs since flux spread is influenced by the surface tension and temperature of the printed circuit board. Alcohol-based fluxes have a lower surface tension than water-based fluxes while water-based fluxes spread more rapidly as alcohol-based fluxes tend to dry faster.

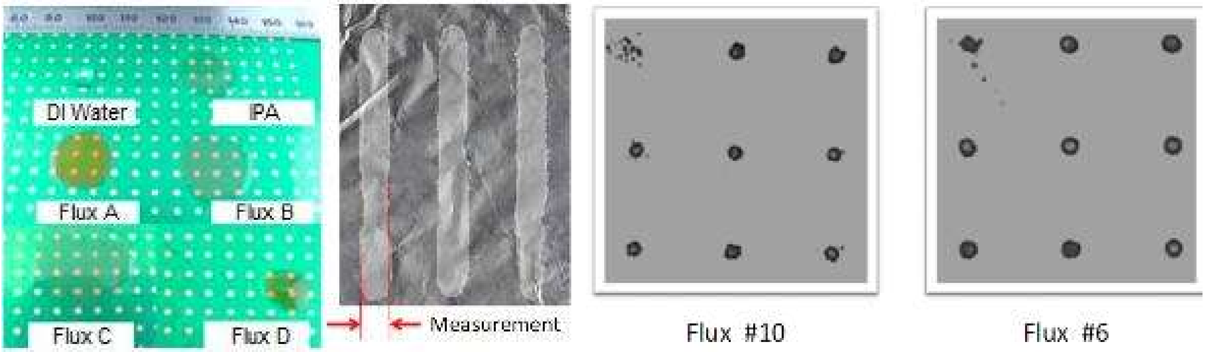

Figure 2. Effects of flux migration (left), and deflected flux satellites after drop-jet dispensing (right) (Kester)

While drop-jet fluxing produces a narrow spray pattern compared to aerosol spray heads with minimal deflection of flux droplets, flux satellites can occur and should be mitigated since they will not be directly exposed to liquidous solder and can result in iconic contamination and potential electro-migration issues if the board assembly must function in a high humidity product environment.

Process Control Essentials

To take full advantage of selective soldering technology, preheating is required to ensure proper thermal activation of a given liquid flux chemistry with the thermal aspects of flux activation such that the topside temperature of a printed circuit board at the end of the preheating cycle is generally specified for proper condition of specific flux type. The total printed circuit board assembly heat cycle consists of the preheat time and temperature as well as the dwell time and contact time with the liquidous solder. This time-temperature profile is greatly affected by the thermal mass differential of the printed circuit board assembly, as well as the rate of heat dissipation of high thermal mass components or fixtures and/or solder pallets.

When selective soldering high thermal mass board assemblies, the solder nozzle alone is not always a sufficient heat source to overcome the thermal mass of large through-hole component leads without preheating the board. Topside and bottom-side preheating in combination with sustained preheating is typically required for multi-layer boards that contain heavy copper ground planes combined with high thermal mass through-hole components to achieve Class 3 destination side fillets.

Design Considerations

Design for manufacturing and assembly (DFMA) is defined as designing a product to be produced in the most efficient manner possible in terms of cost, resources, and time, taking into consideration how the product will be processed, utilizing the existing skill base and minimizing the learning curve as much as possible, to achieve the highest yields attainable.

DFMA is a major concern since many printed circuit board assemblies are designed by designers who have little if any, or limited at best, manufacturing experience. This is especially true for original equipment manufacturers who operate in a virtual manufacturing business model, designing, marketing and selling electronic products while outsourcing the manufacturing to others outside of their own company.

With respect to selective soldering of challenging through-hole components, it is recommended that design guideline attention be given to adjacent component clearance, lead-to-hole aspect ratio, lead projection and thermal reliefs. Adjacent component clearance, or the distance between a though-hole pad and an adjacent SMT pad, is key since under most conditions it is essential the selective soldering nozzle be allowed to over-travel the last rows of component pins to prevent bridging.

Proper consideration should be given to lead-to-hole aspect ratio to ensure complete vertical hole fill of through-hole components. An accepted best practice allows for a maximum aspect ratio of 1.5:1.0 of the plated through-hole (PTH) diameter verses the component pin diameter. It is also imperative that consideration be given to component lead projection to prevent bridging between adjacent though-hole solder joints. An accepted best practice is that the maximum lead projection should be equal to, or less than, one-half the pitch between adjacent through-hole components leads.

It is also suggested that thermal relief design elements be incorporated into printed circuit boards whenever high thermal mass through-hole components in combination with heavy ground planes are employed. Recommended thermal relief design guidelines should include: inside diameter = drilled hole size plus 2x annular ring, outside diameter = inside diameter plus 0.5mm, spoke width = 0.02mm minimum, 0.4mm preferred, and rotate thermal reliefs of alternate layers in multilayer boards by 45 degrees to minimize internal board stress in the Z-axis direction.

Challenging Components

Among the many different types of challenging components are 1.0mm pitch staggered row dual in-line memory module (DIMM) connectors, particularly when soldered into multilayer printed circuit boards with heavy ground planes. Special attention should be given to lead projection and solder nozzle traverse speed to minimize solder bridging of these DIMM connectors

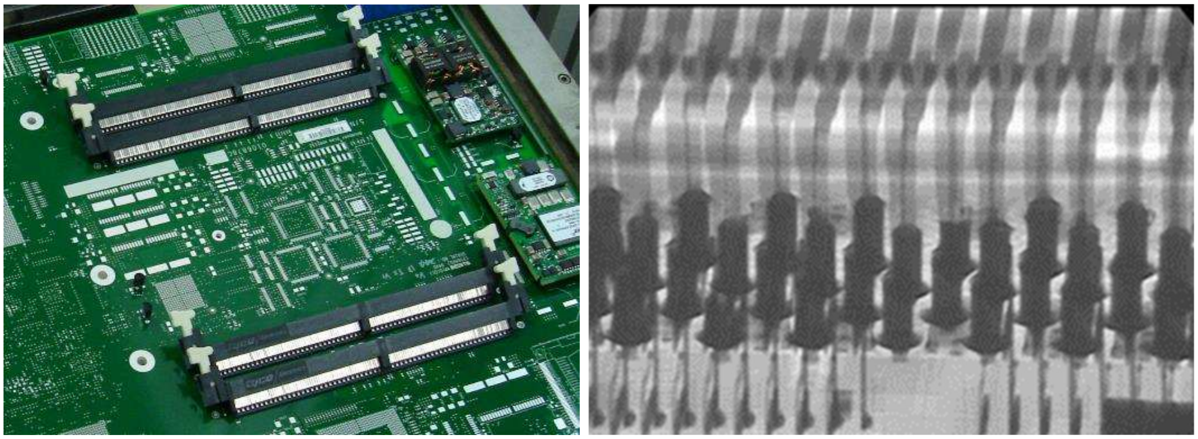

Figure 3. Multiple 240-pin dual in-line memory module (DIMM) connectors mounted in 22-layer printed circuit board assembly (left), and X-ray image of 100% PTH fill (right)

Another challenging component is the 2.0mm pitch six row compact peripheral component interface (cPCI) connector that requires special attention due to the solderability issues of its beryllium copper base metal and gold-plated pins. Since cPCI connectors are often mounted in high density interface (HDI) boards, or into heavy backplanes, they are often held in place with specialized fixtures or pallets which places an additional thermal demand on the selective soldering preheating process

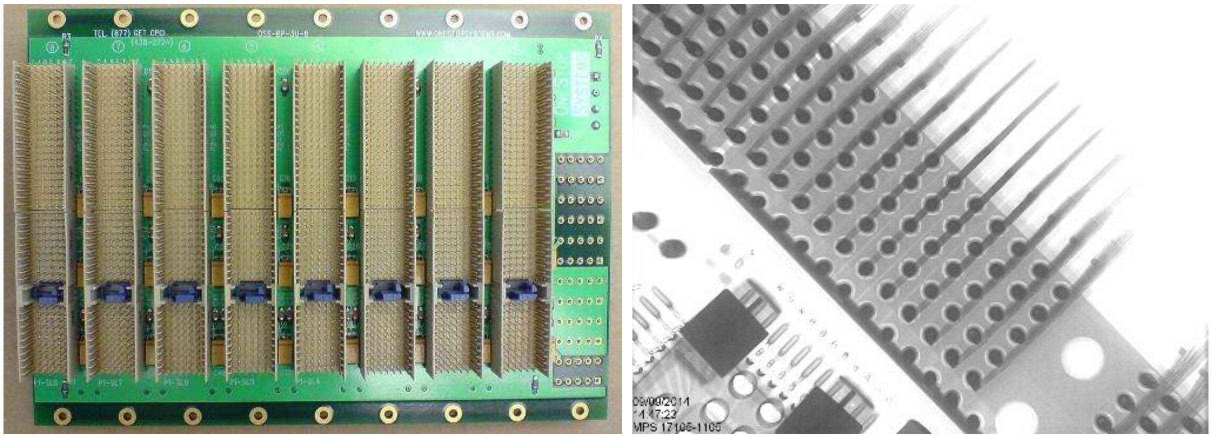

Figure 4. Several 132-pin cPCI connectors mounted in HDI board assembly (left), and X-ray image of complete PTH fill (right)

Fine-pitch through-hole components such as 1.27mm and 1.0mm pitch micro-connectors place a different set of demands on the selective soldering process and typically require special attention to lead projection and traverse speed to minimize bridging between adjacent pins.

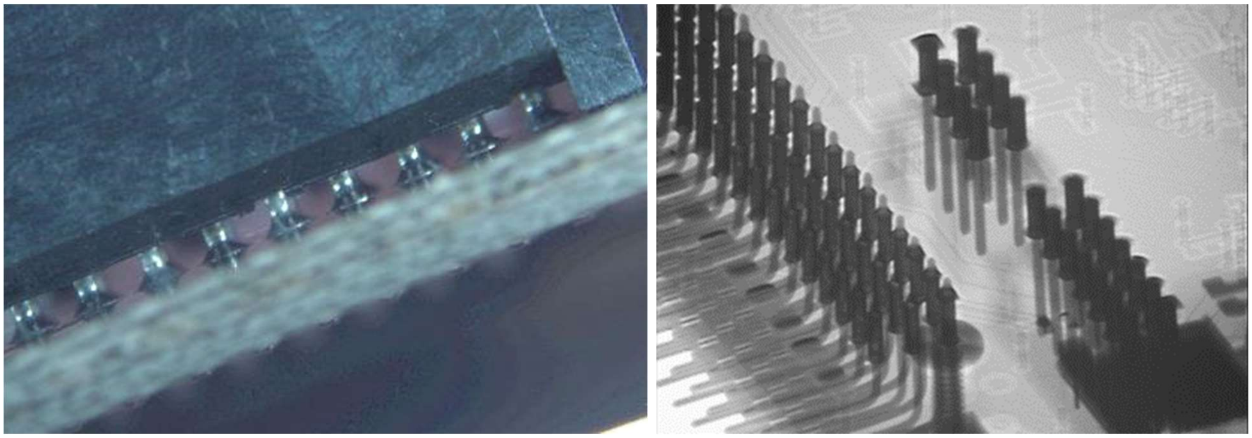

Figure 5. Destination side fillets of 1.0mm pitch micro-connector (left), and X-ray image of 100% PTH fill (right)

Ribbon connectors with a pitch of 1.27mm, and as fine as 0.5mm, can be successfully selectively soldered with the assistance of a nitrogen de-bridging knife.

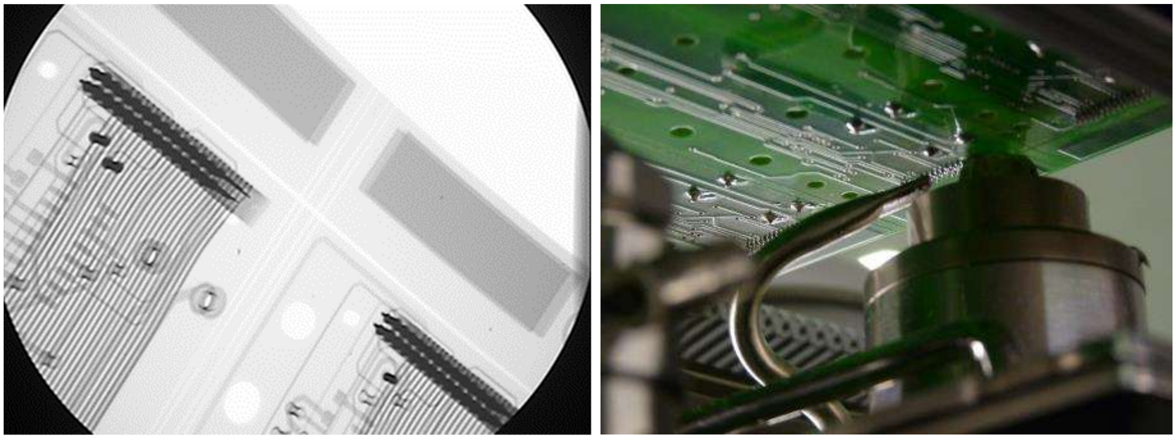

Figure 6. X-ray image of 0.5mm pitch ribbon connectors (left), and nitrogen de-bridging nozzle (right)

Other high thermal mass components including coax connectors, MIL-spec connectors, and ceramic pin grid array (PGA) devices, the latter commonly used in military and aerospace applications, also places additional thermal demands on the preheating process if sustained preheating is not utilized.

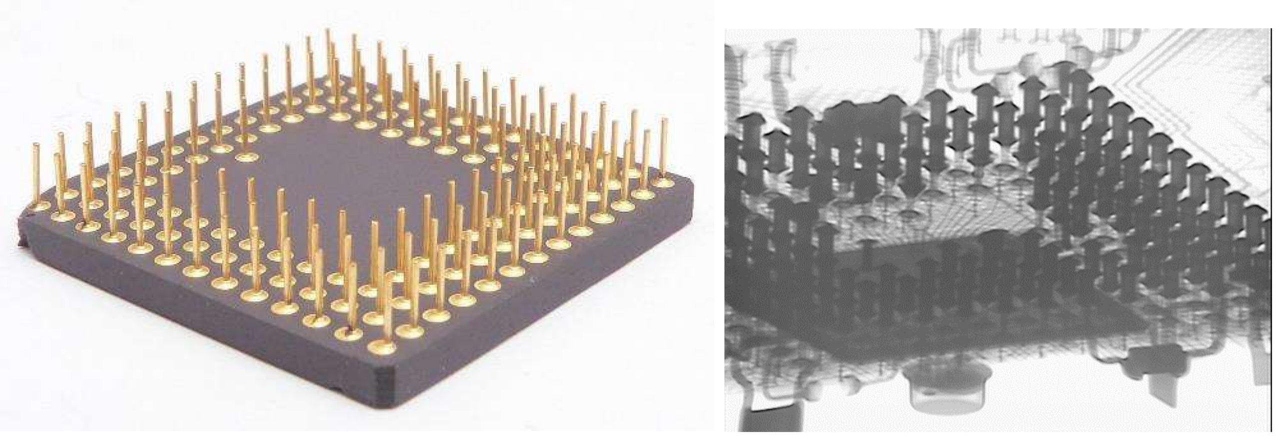

Figure 7. High thermal mass ceramic pin grid array (left), and X-ray image of complete PTH fill (right)

Mitigation of Gold Embrittlement

Immersion gold over a copper base metal is highly resistant to the effects of corrosion since gold does not oxidize and provides a protective layer with a highly solderable surface that is very bondable for both gold and aluminum bonding wires. However, since gold melts at a relatively low temperature, the inclusion of gold within a solder joint can result in gold embrittlement when combined with other metals to form the solder connection interface.

As the gold plating dissolves rapidly during the soldering process, the remnant gold within a solder joint can weaken the integrity of the interconnection. If this gold dissolution is excessive during the solder alloy’s liquidous phase formation, the composition and mechanical properties of the resulting solder joint will change. Gold embrittlement within tin-lead (SnPb) solder joints is a well-known failure mechanism. Commonly used lead-free solder alloys including tin-silver-copper (SAC305) and tin-nickel-copper (SN100C), are more capable of maintaining their mechanical properties when combined with gold partially due to the greater tin content, however lead-free solder joints will also degrade with increased gold inclusion.

Beginning with the IPC J-STD-001 Rev F requirements in 2014, and continuing with the current Rev G, it has been stated that gold shall be removed from: at least 95% of the surfaces to be soldered of through-hole component leads with 2.54µm or more of gold thickness, from 95% of all surfaces to be soldered of surface mount components regardless of gold thickness, and from the surfaces to be soldered of solder terminals plated with 2.54µm or more of gold thickness. With this new criterion, gold removal is therefore required for all high-reliability Class 2 and Class 3 electronic products and therefore affects almost everyone

The removal of gold plating from component leads can be facilitated by a pre-tinning process which removes the gold as it is solubilized in the molten solder during the re-tinning process. A double tinning process or dynamic solder wave may be used for gold removal prior to soldering the components into a board assembly as improper removal of gold on component leads and terminations prior to board level assembly can result in solder cracks and/or field failures.

Solderability Testing

The wetting balance tester, also known as a meniscograph, is an industry accepted instrument used to access component solderability. This wetting balance solderability test method uses a strain gage to measure the buoyancy of a component lead when immersed into a bath of molten solder. The resulting force verses time wetting curves measures solderability with component leads having good solderability exhibiting rapid neutral buoyancy, while oxidized or un-solderable leads typically display slow buoyancy, or retarded wetting.

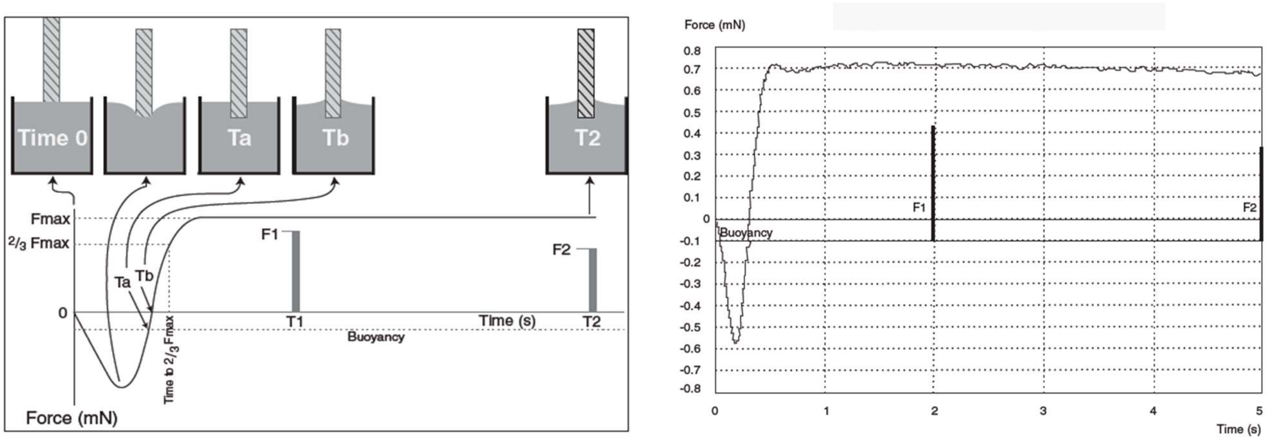

Figure 8. Wetting balance solderability test method (left), and wetting curve of highly solderable lead (right)

Through-hole and surface mount components that exhibit poor solderability can be reconditioned using a component re-tinning procedure after which a major improvement in solderability can be confirmed since an improved intermetallic is achieved during the component re-tinning process

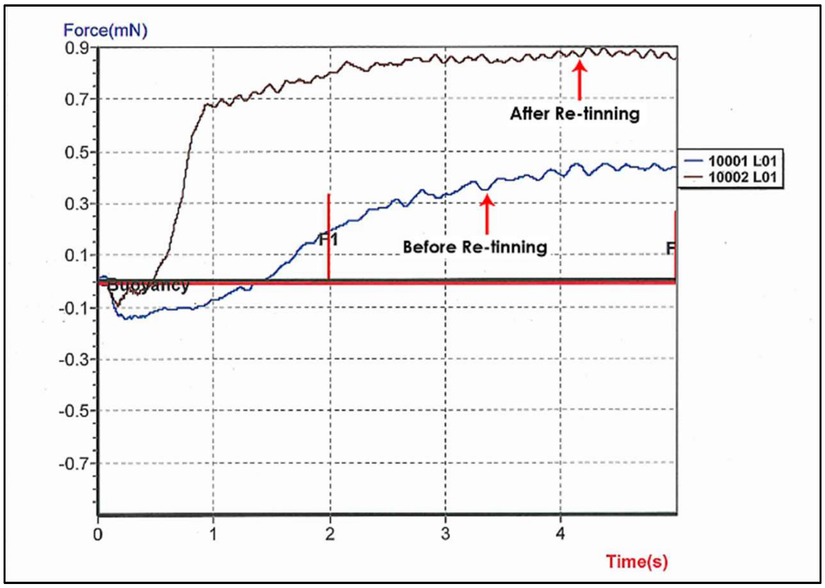

Figure 9. Solderability test results of through-hole component leads before and after re-tinning

Legacy components used for end-of-life (EOL) product builds, may be decades old having been stored in uncontrolled conditions leaving them generally oxidized with poor solderability which can result in poor quality solder joints. Refurbishing these components will replace oxidized, plated finishes that are deemed un-solderable with an intermetallic homogeneous finish that is impervious to oxide growth and will mitigate possible tin whisker growth.

Summary

Selective soldering technology is an essential part of forming interconnections for most electronic packaging and circuit board assembly applications. Solderability is no longer an option for many high reliability segments of the global electronics assembly industry. With implementation of the recent Rev G of IPC J-STD-001, solderability testing, gold removal and component re-tinning have become prerequisites for doing business and remaining competitive in the global electronics marketplace.

This paper is based on a workshop originally presented at the IPC APEX 2019 conference.

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