Best Practices for Evaluating Selective Soldering Systems

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BEST PRACTICES FOR EVALUATING SELECTIVE SOLDERING SYSTEMS • CHOOSING THE RIGHT OPTICAL INSPECTION SYSTEM • GRAPHENE, THE NEW WONDER STUFF? • IMPEDIMENTS TO SOLDER ALLOY FREE ELECTRONIC (SAFE) ASSEMBLY & more

Best practices for evaluating selective soldering systems

Key aspects of the selective soldering process and benchmarking of entry-level platforms

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Selective soldering is certainly not a new process, having been used to solder through-hole components by various industries such as automotive electronics, medical, aerospace and telecommunications. In recent years, many electronics manufacturing companies have continued the use of selective soldering technology during the prototype process to solder newly designed products of greater component density and complexity. This paper examines the evaluation of entry-level selective soldering systems including the benchmarking of key attributes that result in highly flexible selective soldering systems capable of soldering assemblies to the highest quality standards.

Introduction

The continuous drive throughout the electronics industry to design and manufacture new and innovative products has resulted in competitive designs that decrease physical size, consolidate componentry and increase performance characteristics. As a result of these new designs manufacturers of electronic products are forced to contend with the challenge of soldering through-hole components in high thermal mass printed circuit board assemblies (PCBA) together with miniaturized SMT components. Very often these high thermal mass PCBA designs involve thick printed circuit boards with either high layer counts or thick copper ground planes.

While the introduction of selective soldering has proven to be a valuable tool for overcoming many of the challenges associated with soldering of through-hole components in these mixed-technology assemblies, excellent process control is required to ensure the ability to solder high thermal mass PCBAs with a high degree of repeatability. Demanding applications have proven that advancements in flux application, preheating capability and soldering techniques are essential to achieve excellent vertical through-hole fill when soldering high thermal mass PCBAs. These

Features	Platform A	Platform B	Platform C	Platform D	Platform E
Drop-jet spray fluxer	●	□	●	●	●
Ultrasonic fluxer	□	—	□	—	—
Dual flux heads	□	□	□	—	—
Bottom-side preheating	□	—	□	□	●
Topside preheating	□	□	□	□	—
Closed loop preheat control	●	□	□	□	□
Lead-free solder module	●	□	●	●	●
Maintenance free electromagnetic solder pump	●	—	—	—	—
Solder wave height control	●	●	□	●	□
Auto solder wire feeder	●	●	●	□	u
Second solder pot	□	□	—	—	□
Process monitoring camera	□	□	□	□	□
Bar code reader	□	□	u	u	u
Fiducial recognition	□	□	□	□	□
Board warpage detection and auto compensation	□	—	□	—	□

Notes: ● = Standard □ = Optional — = Not available u = Unspecified

Table 1. Comparison of primary features for major entry-level selective soldering systems

same demands must be met by entry-level selective soldering systems when soldering thermal challenging PCBAs in a prototype or new product introduction (NPI) environment.

Comparing equipment choices

There are many selective soldering systems available in the marketplace, ranging from fully automated high-volume systems to entry-level systems for lower volume applications. In addition, several features and options are available for these systems which should be considered based on the demands of a particular application.

Regardless of the selective soldering system utilized, it is essential that the soldering process variables including flux deposition, topside board preheat temperature, solder pot temperature and contact time, as well as the interactions between these process variables, be fully optimized in order to develop a robust process for thermally challenging high mass PCBAs.

> *Regardless of the selective soldering system utilized, it is essential that the soldering process variables and the interactions between these variables be fully optimized.*

When conducting a side-by-side comparison of the major entry-level selective soldering system available in the market today, it becomes apparent that many system features are available as additional options, which should be considered when comparing capital investment (*Table 1*). Recently some globally sourced low-cost selective soldering machines have become available in the North American market. We do not advocate the use of these machines since they have limited process capability as well as questionable process repeatability.

In additional to comparing the available features of the major entry-level selective soldering systems, it is recommended that a review of the specifications also be conducted to determine which of these systems will meet the specific requirements of a given application in terms of board size, component clearance and preheating capability (*Table 2*).

During the evaluation process, a side-by-side analysis should also be done of the fluxer, preheat control methodology and solder bath temperature range to determine which platforms will best meet the product requirements foreseen for both current and future production needs[1].

Beyond reviewing the specifications of the candidate entry-level selective soldering systems, it is also recommended that sample PCBAs be soldered and undergo cross sectional analysis using either potting and polishing with optical inspection or X-ray inspection to verify through-hole vertical fill as a final step in the evaluation process leading up to a purchase decision[2]. X-ray analysis is an excellent tool to confirm that the final system chosen is capable of achieving vertical through-hole fill of greater than 75% and that the platform chosen is

Specifications	Platform A	Platform B	Platform C	Platform D	Platform E
Maximum PCB width	16" (406mm) Std. 20" (508mm) Opt.	12" (305mm) Std. 18" (457mm) Opt.	18" (457mm)	19.6" (500mm)	16.1" (410mm)
Maximum PCB length	20" (508mm) Std. 24" (610mm) Opt.	12" (305mm) Std. 24" (610mm) Opt.	20" (508mm)	19.6" (500mm)	16.1" (410mm)
Topside PCB clearance	4.7" (120mm) * 7.5" (190mm) **	u	7.4" (190mm)	2.4" (60mm)	3.5" (91mm)
Bottom-side PCB clearance	2.4" (60mm)	u	1.5" (40mm)	1.2" (30mm)	u
PCB edge clearance	0.1" (3mm)	u	0.1" (3mm)	u	0.15" (4mm)
Maximum PCB/pallet weight	18 lb. (8 kg)	u	u	u	11 lb. (5 kg)
Bottom-side preheat method	Infrared	Latent heating	Heated nitrogen	Halogen lamp	Infrared
Bottom-side closed loop preheat control method	Thermocouple	—	—	u	u
Bottom-side preheat output	12 kW	u	u	900 W	9 kW
Preheat temperature range	0-200 °C	u	u	u	u
Topside preheat method	Convection	Infrared	Infrared	Infrared	—
Topside closed loop preheat control method	Thermocouple	Optical pyrometer	u	u	—
Topside preheat output	5 kW	3 kW	2.5 kW	7.5 kW	—
Solder volume (tin-lead)	29 lb. (13.1 kg)	30 lb. (13.6 kg)	18 lb. (8.1 kg)	42 lb. (19 kg)	88 lb. (40 kg)
Maximum solder temperature	320 °C Std. 450 °C Opt.	400 °C	350 °C	320 °C	u

Notes: ● = With top preheating □ = Without top preheating — = Not available u = Unspecified

Table 2. Comparison of specifications for major entry-level selective soldering systems

capable of delivering consistent through-hole fill across all pins regardless of the heat sinking effects of ground planes or inner layers. For certain critical applications manufacturers require and are inspecting for 100% vertical through-hole fill. It may also be recommended to add thermal reliefs in heavy copper ground planes or inner layers since experience shows that in some cases it may not be possible to achieve 100% vertical through-hole fill without using this type of design feature.

Since maximum flexibility is required in many production environments, entry-level selective soldering systems that have the ability to process different flux types or different solder alloys at the same time should be considered (*Table 3*). System capabilities that provide a high level of process control, such as dynamic wave height control, volumetric flux control and automatic solder replenishment should also be considered.

An additional factor to consider when comparing entry-level selective soldering systems is the use of servo motor drives versus stepper motors. While servo motor drives are slightly more costly, they make a selective soldering system more capable and reliable in terms of positioning.

Preheat selection

Typically the preheating method and its parameters are chosen according to the thermal demands of the PCBA as well as the flux chemistry. High density PCBAs or board assemblies with a high layer count or a high number of interlayers or high thermal mass components will place an additional burden upon the preheating system. It is of particular importance that the temperature profile recommended by the flux manufacturer be maintained during the solder process despite the thermal demands of a high mass PCB or high thermal mass components.

High density PCBAs or board assemblies with a high layer count or a high number of interlayers or high thermal mass components will place an additional burden upon the preheating system.

There are four primary methods of preheating available for selective soldering systems including, latent heating, infrared (IR) heating, convection heating, or combination IR/convection heating. Latent heating is the heat radiated from the solder pot and solder nozzle, is of limited capability and is slow to heat a PCBA to the required temperature. Medium wave length IR heating has a rapid response rate and is flexible enough for most types of flux. Convection heating has a lower gradient and heat transfer rate while exhibiting greater uniformity. Combination IR/convection heating is beneficial for high thermal mass applications such as PCBAs with high thermal mass through-hole components, high layer count multi-layer circuit boards or assemblies with heavy ground planes.

The type of preheat control is also very important to assure proper control over the preheating process. Closed loop control is essential with feedback from a thermocouple to control the heating source and compensate for different thermal loads and operating conditions. An ideal situation is to have sufficient closed loop control

Capabilities	Platform A	Platform B	Platform C	Platform D	Platform E
Dual flux heads to run different flux types in mixed production	□	□	—	—	—
Dual flux heads adjustable to flux two boards at same time	□	—	—	—	—
Segmented top preheating	□	—	—	—	—
Closed loop heated nitrogen	□	—	—	—	—
Dynamic solder level monitoring	●	●	●	●	□
Dynamic wave height monitoring	●	●	□	●	□
Dual integrated solder pots for different alloys or nozzle sizes	□	□	—	—	□
Dual solder pots adjustable to solder two different boards at same time	□	—	—	—	u
Auto solder pot exchange	□	□	—	—	□
Wave soldering nozzle	□	□	—	u	u
Compatible with HMP solder alloys	□	□	—	u	u
Operation via touch screen	□	—	—	●	—
SMEMA interface	□	—	—	—	●
CAD data download	□	□	□	u	□
Off-line programming	□	□	□	□	□
Optical solder wire feeder for poka-yoke detection	□	u	u	u	u
Traceability per SAE/ZVEI standards	●	—	—	u	u

Notes: ● = Standard □ = Optional — = Not available u = Unspecified

Table 3. Comparison of principal capabilities for major entry-level selective soldering systems

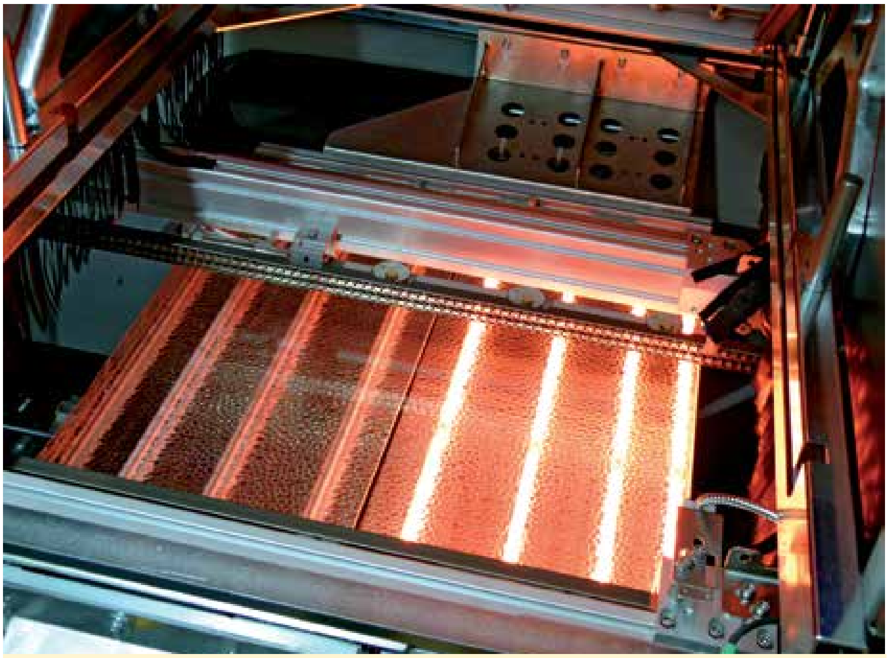


Figure 1. Full area bottom-side IR preheat module with emitters switchable to match preheat requirements.

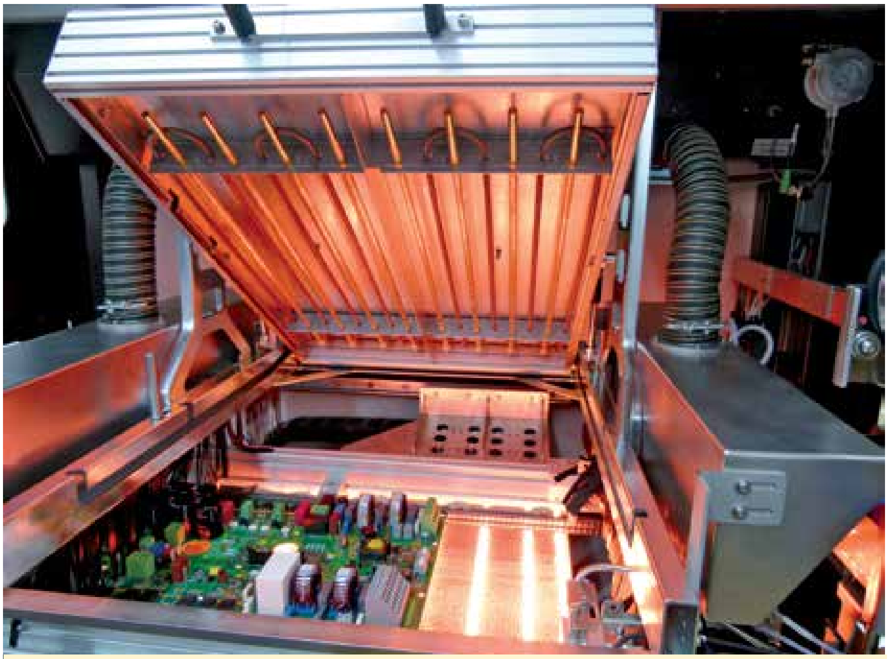


Figure 2. Topside convection preheat module ensures sustained preheat throughout soldering cycle.

so that a Cpk (capability process index) of greater than 1.00 can be achieved with the surface temperature across the entire PCBA varying no more than ±5.0˚C from the mean. This type of entry level selective soldering system can achieve very good board-to-board thermal repeatability.

Some entry level systems utilize an optical pyrometer to measure the surface temperature of the PCBA and use this measurement method to control the preheating process. These systems typically can only control the average PCBA surface temperature within a range of ±15.0˚C and only within the field-of-view (FOV) of the optical pyrometer rather than the entire area of the PCBA. Since an optical pyrometer senses the average infrared energy emitted from the surface it is aimed at, it is susceptible to different colors of PCB material, reflective components, closely packed light colored SMT components, as well as numerous other factors that can result in a PCBA temperature range of as much as ±20.0˚C.

An improved method of preheating is an entry-level selective soldering system equipped with a full area bottom-side infrared preheat module with emitters that can be switched in groups to match their output to the thermal requirements as well as the size of the PCBA (*Figure 1*).

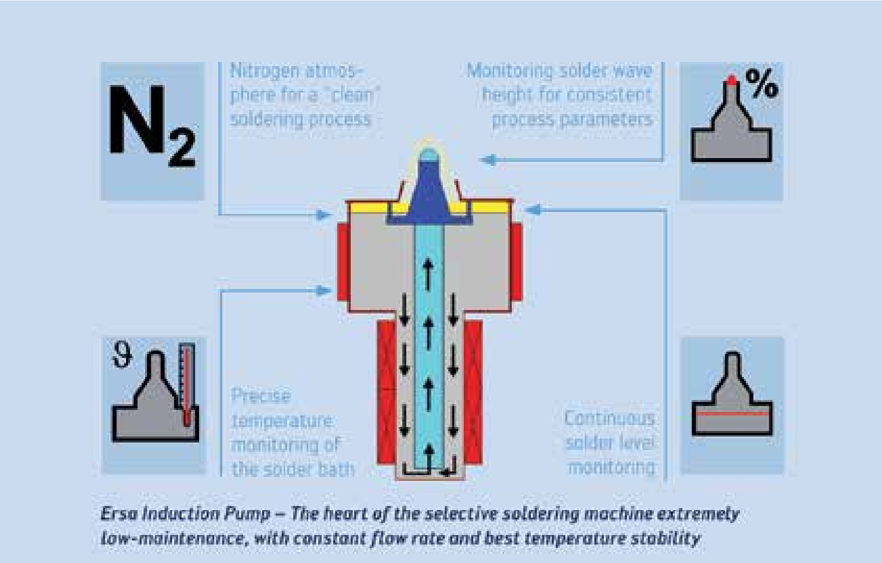
When used in conjunction with a topside convection preheating module, this combination of bottom-side infrared and topside convection preheating yields highly effective and reproducible results for thermally demanding applications of high layer count and/or high thermal mass assemblies. Studies have shown that the use of topside convection preheating together with bottom-side infrared preheat allows the PCBA to reach soldering temperature without destroying the flux activators prior to soldering.

Sustained preheat

Some large or high thermal mass PCBAs can be challenging for any through-hole soldering process and particularly troublesome for certain selective soldering systems where the preheating is applied only to the bottom of the board assembly. The ability to apply topside preheating continuously throughout the entire soldering cycle is critical to achieving high quality results when soldering thermally challenged assemblies. The use of sustained topside convection preheating promotes capillary action of the molten solder and increases the vertical hole fill within plated through-hole barrels as well as the formation of topside solder fillets (*Figure 2*). In addition, the use of sustained topside convection preheating improves the thermal distribution as well as the solderability of difficult assemblies. Topside convection preheat is not practical or possible for selective soldering systems that grip and robotically move the PCBA since the topside preheater would have to travel with the PCBA and gripper mechanism.

To maintain solder joint quality the control of the topside convection preheating is critical. Systems that use closed loop feedback from a thermocouple to control the heating source can control the topside surface temperature of the PCBA within a range of ±5.0˚C.

It should be noted that while the use of sustained preheat is an advantage for improving solder joint formation and



Ersa Induction Pump – The heart of the selective soldering machine extremely low-maintenance, with constant flow rate and best temperature stability

Figure 3. Maintenance free electromagnetic solder pump produces vortex-free, stable wave height.

through-hole vertical fill, sustained preheat does not alter the intermetallic thickness or intermetallic microstructure.

Wave dynamics

The solder pot and solder pump mechanism of a selective soldering system should be of a good design in order to deliver reliable performance as well as being easy to maintain. The solder pump should deliver uniform and stable control of solder flow so that the wave dynamics create a smooth flow at the solder nozzle tip. Solder nozzles should also be of a good design since they can reach operating temperatures of 290˚C when operating with tin-lead solder alloy and to as high as 420˚C when used with high melting point (HMP) solder alloys. At the same time solder nozzles should have minimal thermal deformation and inner stress making their removal and cleaning easy to perform.

There are three primary types of solder pumps available for selective soldering systems including, impeller pumps, vane pumps and electromagnetic pumps. Impeller solder pumps are low in cost but generate a vortex in the solder bath and are susceptible to wave height fluctuation. Vane solder pumps create less of a vortex and therefore maintain a somewhat more stable wave height. Electromagnetic solder pumps have the significant advantage of having no moving parts, do not create a vortex thus having a very stable wave height and also create very little dross. Frequency controlled, servo driven electromagnetic solder pumps ensure very constant flow rates and offer precision control over solder wave height (*Figure 3*). Since an electromagnetic solder pump has no moving parts it has the added benefit of being virtually maintenance free.

An important process control capability is dynamic wave height control. This control system should have the capability to maintain the height of the solder at the solder nozzle tip within a range of ±0.005" or ±0.13 mm which is critical when selective soldering fine-pitch through-hole components. Dynamic wave height control is particularity effective when working with smaller diameter solder nozzles or when soldering in tight adjacent clearance areas.

Traceability

The high quality demands placed upon the electronics manufacturing industry, especially automotive electronics, medical and aerospace, have created greater emphasis on traceability and a secure means of tracing and documenting product and manufacturing processes. The Society of Automotive Engineers (SAE) in conjunction with the German Electrical and Electronic Manufacturers' Association (ZVEI) has developed a SAE/ZVEI traceability standard commonly used in Europe and North America.

Entry-level selective soldering systems are available that ensure full compliance with the SAE/ZVEI standard including an extensive alarm management file structure. All occurring traceability messages are time stamped and coded with user identification and stored in an XML protocol making all traceability data available to higher level systems such as a management execution system (MES).

Conclusion

The continued use of selective soldering is increasing the development of entry-level selective soldering systems. While many entry-level systems are available in the marketplace, it should be kept in mind that you do not have to sacrifice machine quality as some entry-level selective soldering systems use the same core technologies as leading edge technology high-volume selective soldering systems.

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