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SELECTIVE SOLDERING TECHNOLOGY SELECTION

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ABSTRACT
Selective soldering is not a new process. It is already exists and used 30 years ago for through-hole component by different industries for automotive and medical products. Now most manufacturing industries are moving forward on SMD's miniaturization to reduce PCB complexity and balance component density on the board to ensure a good assembling process. By this concept, why selective soldering still utilized and used? Does it because of component reliability, uniqueness or complexity having this in mind next question will be which platform will best fit for the product

This paper describes the evaluation process of selecting technology for selective soldering. Low-cost and High -cost platform are classified in this paper as Platform A and B respectively. It is expected to magnify the essential difference of each platform through comparative analysis and simulations during the study. Consider both platforms are built in same concept but different performance which influences productivity. Understanding selective soldering is very important to avoid cost of quality and throughput deficiency during production.

In the study, design consideration showed that parts and functions influence the solderability during soldering process. Actual simulations on fluxer, pre-heat, solder bath and side by side analysis between nozzle materials will be evaluated. Also, cost of capital investment of each platform is taking into consideration.

This paper aims to provide information for selecting a selective soldering platform and serves as reference for manufacturing company having same process and application that might need in their operations.

Key words: Selective Soldering, Mixed Technology, Platform, and Manufacturing, Guidelines

INTRODUCTION
Selective soldering is not a new process. It was already used since 1980's on limited scale production for products using through- hole components.

Which platform is suitable for the products will be a challenge for manufacturing company, given the fact that customers are always asking for price reduction per unit without jeopardizing the product quality. Base on our experience in dealing with production needs for selective soldering there are three major items to consider such as Volume, Cycle time and Quality.

It is best to have a better cycle time but many factors affect the cycle time like the conveyor design, parameter settings and number of joints intended to solder. Short cycle time can be achieved by locating the part processes beneath the conveyor and using robot time for the soldering process only.

Last but not the least is the quality aspect, understanding that there are several factors affecting the product quality like materials, design, process parameters, handling and equipment induced error.

EXPERIMENTAL
Materials
I. Flux, Alpha Metal SLS 65
II. Solder Bar, SAC 305 RoHS compliant
III. Panel PCB, 280mm x 200 mm x 1.6mm+/-0.2mm including solder mark with 4 copper layers, 2 ink layers
IV. PCB Jig (Metal)

Concept on Soldering
The process concept of platforms in this paper was classified as follows:

Concept	Platform A	Platform B
Process 1	Loading	Loading
Process 2	Fluxing	Fluxing
Process 3	Preheat + Soldering	Preheat
Process 4		Soldering

Figure 1. Machine basic concept

Figure 1. shows side by side information of selective soldering simple process for both platforms to be used in this study. Platform A simplified their processes by putting preheat on top while doing the soldering which make it footprint much smaller than platform B.

Platform B used normal process of soldering as shown also in Figure 1 which makes the footprint much longer than platform A.

A thorough understanding of the process and how the equipment fulfills the need is the key part of the synergy that must develop between the user and equipment manufacturer.

PCBA Loading (PCB + Solder Pallet)

PCB loading may varies depends on the solder pot design. It may look simple but really impact the process

Lets take a look on Figure 2, platform A loaded in the direction parallel to its length in which no bending occurs while platform B loaded parallel to the width which experienced bending during the process.

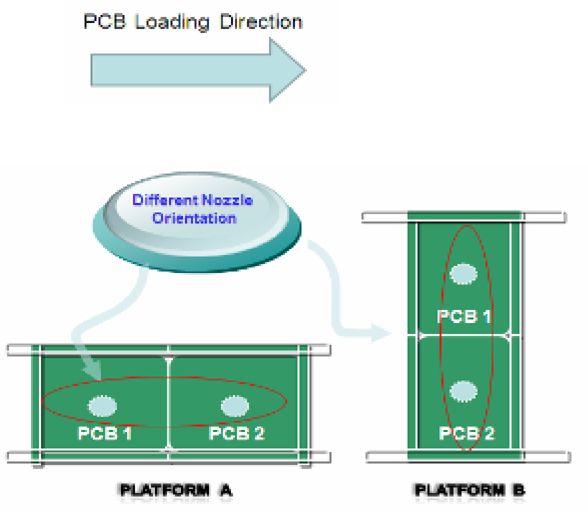

Figure 2. PCB loading and Nozzle Orientation

Nozzle orientation influences the PCB loading for a twin nozzle configuration. Figure 2 shows how the nozzle orientation affects the PCB loading.

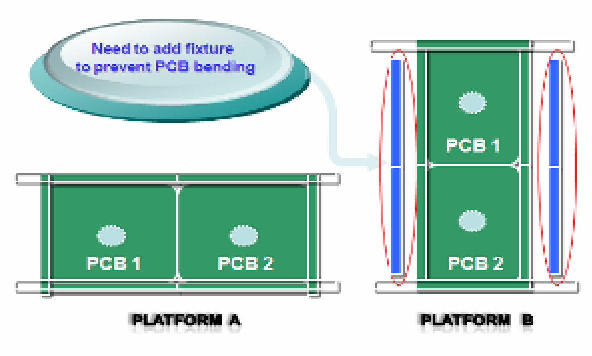

Figure 3. Fixturing

Figure 3 shows that fixtures were used to support the PCBA loaded along its width on platform B to prevent PCB bending during soldering.

Fluxing

Platforms in this study are integrated by a programmable, precision micro drop fluxing system for selective point or track fluxing with automatic spray accuracy control as shown in Figure 4.

Description	Platform A	Platform B
Fluxer Speed	50 dots/sec	60 dots/sec
Flux spray formation	4.0 – 6.0 mm	3.0 – 8.0mm

Figure 4. Fluxer Specifications

The flux head delivers an absolutely precise & defined amount of flux to the smallest areas on the PCB. The flux pattern on the joint or PCB can be focused dots or tracks of flux as small as 3 mm in diameter or larger!

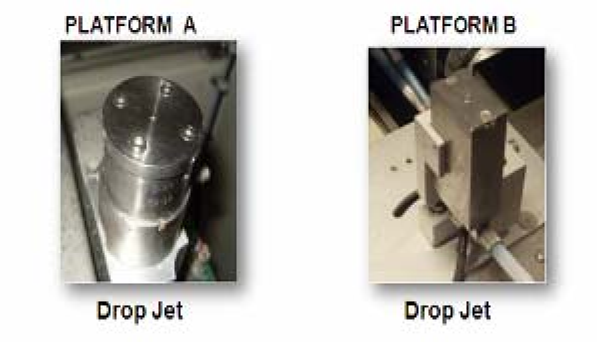

Figure 5. Drop jet dispenser

The flux application method is defined by the number of solder joints and the layout. The available cycle time depends on the layout of component to solder.

In our study there is no much difference on the drop jet dispenser for both platform A and platform B as shown in Figure 5. Both are performed well during mass production testing. No issue of clog or misalign was encountered

Preheating

The preheating process and its parameters are chosen according to the demand of soldering heat required by the flux use and the PCBA assembly whether high density or not. In case of multi-layers with an increasing number of internal layers, heavier components and different component specifications, the preheating system need to be very flexible.

It is particularly important that the temperature profile gradients and the resistance against soldering heat are observed in accordance with the component specifications especially for those components that are not SMD's classified.

The soldering process requires that the assemblies be preheated before soldering starts. Heating is necessary for several reasons:

I. The solvent part of the flux must be evaporated before soldering begins; otherwise, spattering during soldering will occur resulting to solder balls and poor solder quality.

II. As for thermal solderability of the assembly, if the board is too cold, the heat from the solder will flow away into the assembly instead of supplying this necessary heat to the solder joint. Poor through-hole penetration will occur.

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III. To reduce thermal stress in the assembly by creating a more homogenous temperature in the assembly.

Figure 6. Top Preheat **Figure 7.** Bottom Preheat

In this study it shows that bottom preheat take the advantage from top preheat because it easily dry up the flux and heated the leaded parts of the component before the board reaches the soldering stage. A sustained heat up the printed circuit board assembly during selective soldering greatly improves the wetting action of lead-free alloys. Figure 7 is the actual photos of bottoms preheat.

Applying top preheat (Figure 6) alone cannot guarantee that the flux beneath the boards are totally dry and might form a residue after soldering which can only be removed by brushing or washing which is an additional process that will directly impact the cost of manufacturing

Although application may vary depending on product complexity or vice-versa, it is recommended to conduct material evaluation on flux to determine the most applicable flux for your product

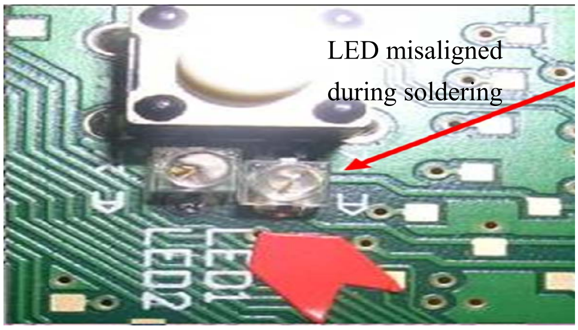

Figure 8. Component float

In some cases where parts need to be covered to prevent tilting or floating like putting weights on top of the component to like in Figure 8 will not need top preheat

Solder Module

Good design of the solder pot should deliver good performance, reliable and easy to maintain. Both platforms use twin nozzle soldering module as shown in Figure 9.

Base on this study, a good design solder pot can help to prevent part damaged or broken once it is removed from the solder pot Figure 10 is an example of poor design pump that easily broken during maintenance. Cast iron must be designed not only for high temperature but also for more frequent removal during maintenance.

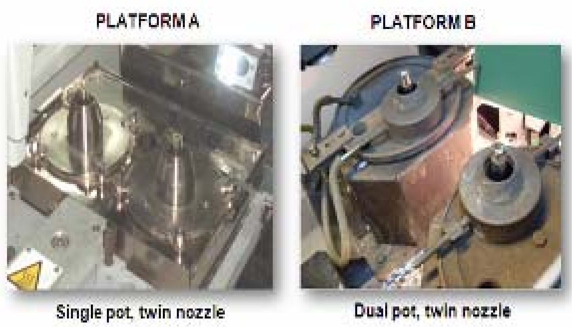

Figure 9. Soldering module

Figure 10. Broken pump (Platform A)

Both platform A & platform B use twin nozzles in soldering as shown in Figure 9. Platform A has single bath with single pump but used twin nozzles and platform B has two solder bath with two individual pumps. Pump configuration is very important to deliver the required power to ensure the melted solder flow over the nozzle tip.

Response on High Volume Production

Poor design will affect the soldering quality directly. Design concept of platforms might be similar but reliability will be the great challenge in selecting selective soldering technology.

Nozzles

In this study both platforms use a wettable nozzle. Platform A used pure iron and platform B used a thin coated material. On mass production testing the nozzle life of platform A is about 3 weeks and platform B last for 8 weeks base on 22.5 hrs x 6.5 days operation.

Figure 11A shows the dimension and geometric figure of the nozzles use in this study.

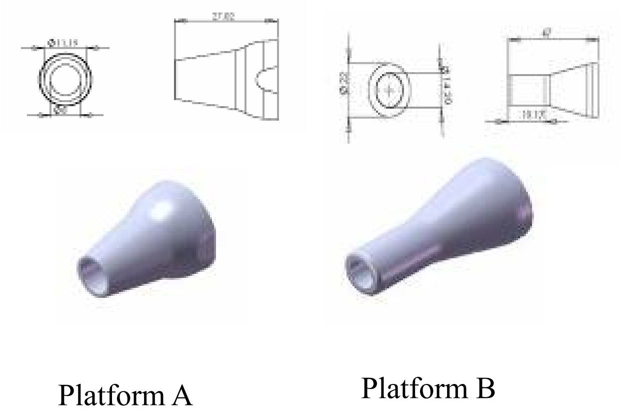

Figure 11A. Nozzle Type

Thermal Simulation on Nozzle

Both nozzles are determined expanding both longitude and latitude upon reaching the temperature of 290 °C. Using the similar thermal expansion coefficient, the thermal deformation and inner stress is different for two platforms due to different structure design. Figure 11B illustrated the thermal deformation comparison for two nozzles. Nozzle A expanded similar amplitude on latitude and longitudinal directions, while nozzle B exhibits very small deformation in latitude.

The maximum displacement on nozzles happened on tips, which firstly to damage during soldering but expansion is not too much to affect the soldering consistency.

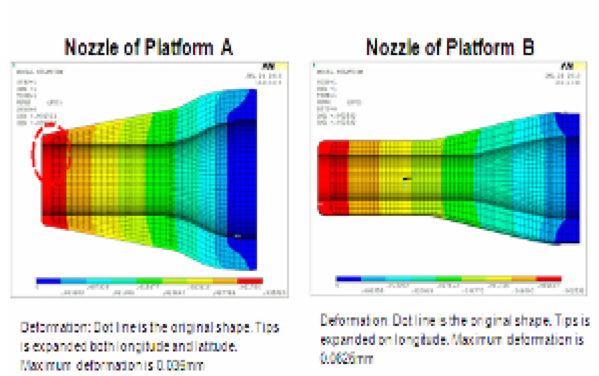

Figure 11B. Thermal stress on tip

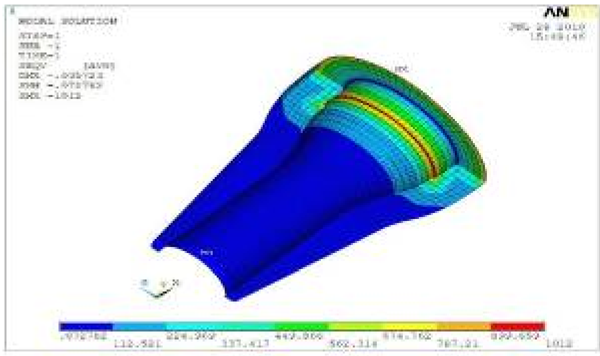

Figure 11C. Thermal stress on bottom (Platform A)

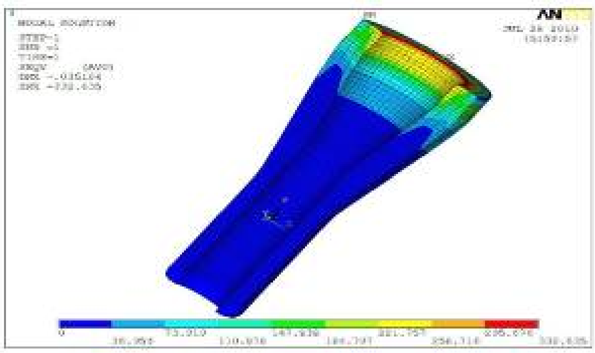

Figure 11D. Thermal stress on bottom (Platform B)

Both nozzles are fixed on the bottom. Figure 11C illustrated stress of nozzle A, which is connected to base with screw thread. Maximum stress of nozzle A is on the thread-end region, and much larger than that of nozzle of platform B as illustrated on Figure 11D. It can explain the phenomenon

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that nozzle A is difficult to be removed from the threaded assembly during replacement or maintenance and nozzle of platform B can be easily removed and replaced due to less stress of base part occur.

Nitrogen

The use of nitrogen in selective soldering process is a must and should be included in any estimation of operating costs. Nitrogen diffused directly on the area of the components being soldered to provide good solder joint. It reduces the formation of dross and aid in creating a more stable and predictable flow of the solder from the nozzle.

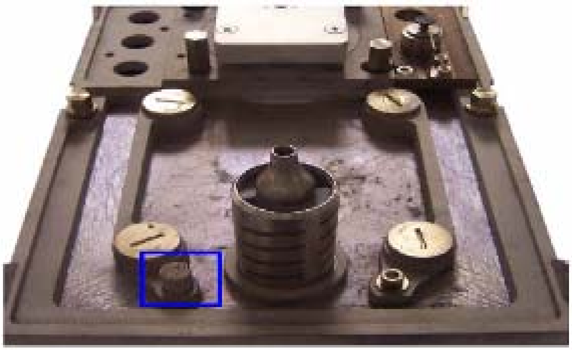

Figure 12. N2 supply (Platform A)

Figure 12 shows that N_2 supply is embedded on the solder pot, once the shroud or diffuser is being damaged the solder can easily clog the path.

Figure 13. N_2 supply (Platform B)

Figure 13 shows that N_2 supply for platform B is delivering directly on the top of the solder pot covered by a sealed metal to ensure that N2 will effectively reduce the air to prevent dross formation.

PCB Design

PCB design rule is mostly related to clearance area around the solder joints. In our study component wash off was encountered due to PCB design issue.

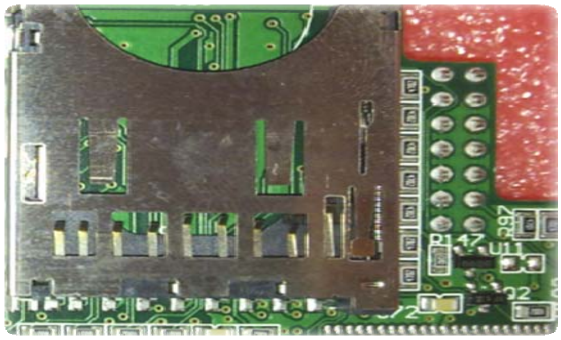

Figure 14. Clearance issue

Figure 14 shows taping was implemented due to poor clearance design between joints to be soldered and SMD's components which are too narrow (<1.2mm).

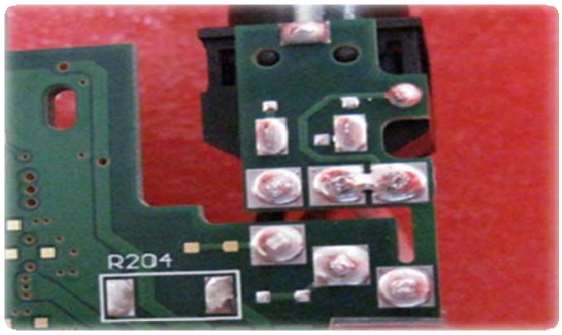

Figure 15. Bridging issue

Solder bridging as shown in Figure 15 was a buildup of solder between leads or pads, causing a short. Solder bridges occur when the solder does not separate from two or more leads before it solidifies.

To prevent it use a correct design: short component lead length and small pad and pitch between the pins. Use a strong flux and optimize the amount. Use a debridging tool if available.

PRODUCTIVITY

Yield is the main differentiator. Low cost platform performs worst in getting consistent quality output on high volume production. High cost platform performs well in getting consistent quality at same condition with low cost platform.

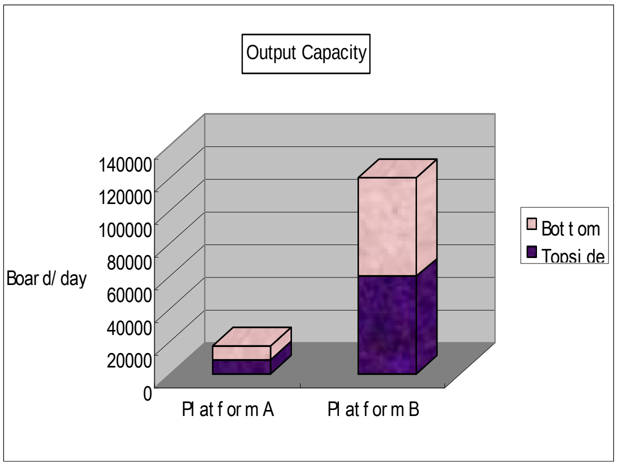

Figure 16. Output Capacity

Data on output capacity were collected on one month continues production. Figure 16 show that platform B produces more board per day compared to platform A while running at same utilization. Platform A experience most of the failure and issues that affect its productivity.

Issues That Affect Productivity

Most of the problems observed during the study is contributed by platform A while platform B remains consistent in meeting good solderability during mass production testing.

Figure 17. Deformed nozzles

Deformed nozzle as shown in Figure 17 was due to heat expansion and etching result to unbalance solder flow that affect the soldering performance of the machine.

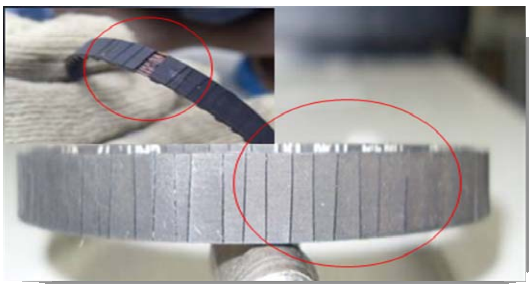

Figure 18. Worn out timing belt

Worn-out timing belt as shown in Figure 18 occurs after a couple of months using platform A, the first thing come to our mind is design issue "belt might not properly design for high temperature application".

On the evaluation we found out that "yes" the belt is not design for high temperature but going back to the design details of its pump assembly it has an air cool system to maintain a lower temperature which the belt can withstand at <75 ^{o}C but not in most cases. During machine shutdown both pump and belt exposed to high temperature of <200 ^{o}C because air will be the 1st to turn-off once power is cut.

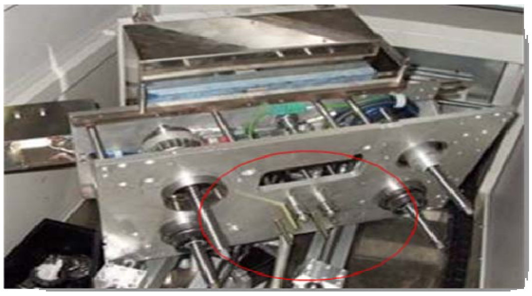

Figure 19. Defective lead screws

Broken Z-lead screw as shown in Figure 19 was an isolated case for platform A. During mass production testing, platform A shows inconsistency of soldering and gradually drops the yield. There is no recommended action but to replace with a new one and perform re-calibration after putting a new one.

Figure 20. Broken N_2 shroud

Broken nitrogen shroud as shown in Figure 20 makes the solder to clog the N_2 system and makes the solder oxidized.

Issues that Affect Quality

Process parameters are very important on selective soldering. Defects and several issues can happen to any of the platforms whether it is low cost or high cost. The key differentiator will be the stability and consistency of soldering.

Figure 21. Insufficient Solder

Insufficient solder as shown in Figure. 21 were due to worn-out nozzle that produce unbalance solder meniscus on its tip that is critical during soldering. To avoid this issue a proper maintenance and good flux application are recommended

Figure 22. Insufficient hole penetration

Insufficient hole penetration as shown in Figure 22 occurs when the solder has not traveled to the top of the plated through-hole and does not cover the pad on the board topside. It can be prevented by increasing the solder temperature, stronger flux activity, or check the nozzle condition.

Figure 23. LCD Discoloration

LCD Discoloration as shown in Figure 23 occurs when the LCD component exposed to a pre-heat with temperature higher than 100°C. To prevent it, use a bottom preheat or fabricate a fixture to cover the topside of the LCD to prevent any exposure to high temperature.

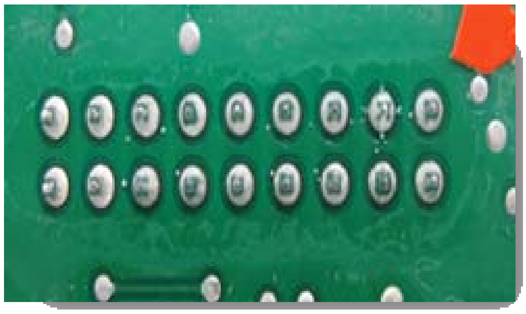

Figure 24. Solder ball

Solder balling as shown in Figure 24 occurs when tiny balls form around components. An increase incidence of solder balling may be seen in some solder mask due to the increased soldering temperatures associated with Pb-free soldering. Solder ball in between the pins may be caused by poor flux activity. This can be prevented by changing the solder mask; optimize solder temperature, or use correct flux.

RELIABILITY ON PRODUCT

Environmental Test Conditions

The objective of the qualification testing is to verify the end product reliability that produced on both platforms. Standard use as reference is JEDEC Standard for Thermal cycling (JESD22-A104-B). Refer to Figure 25 for thermal cycling criteria and Figure 26 for the thermal graph

Ambient Conditions	24 □, 65%RH
Samples quantity:	4 PCBA
The following is the test criterion	
High temperature TB	(80 ± 2) □
Low temperature TA	(-40 ± 3) □
Ramp of temperature	(5 ± 1) □/min
Dwell time t1	15 min
Cycle	200 cycles

Figure 25: Thermal cycling criteria

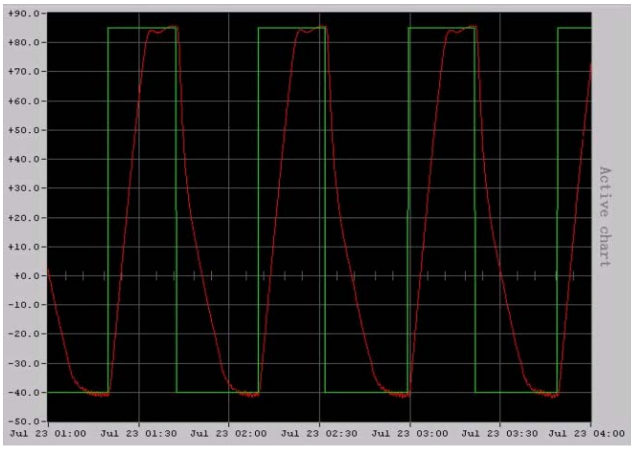

Figure 26: Thermal cycling conditions

The environmental test result of both samples is as follows.
1. No obvious change on cosmetic of solder joints after the thermal cycling
2. Thermal cycling for thin boards shows no obvious difference on hole-fill between product run on platform A and platform B. No obvious appearances of abnormal were observed.
3. Both samples passed thermal cycling test

Through Hole Penetration

X-ray analysis was used to inspect through-hole penetration. Selected vias were inspected as shown in Figure 28 and Figure 29 which is a header connector.

Both platforms able to penetrate the solder on the component joints since the test vehicle used for the evaluation are thin boards. The output of the inspection was 0 and 1. A value of 0 was assigned to those solder joints with a through hole penetration less than 75%. A value of 1 was assigned to those solder joints with through-hole penetration is equal to or greater than 75%.

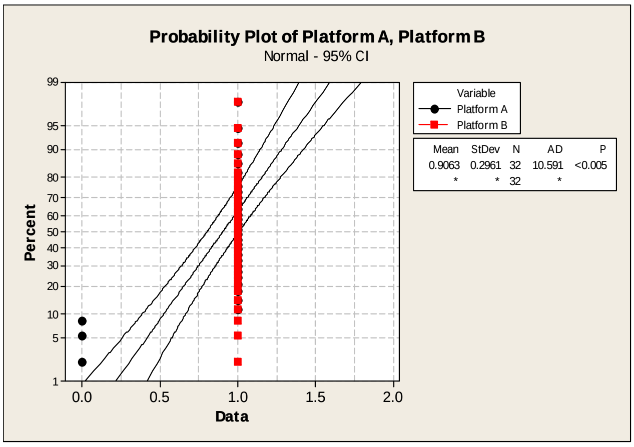

Figure 27. X-ray probability plot

Graph as shown in Figure 27 was based on the sampling data of the test board use for this study. It shows that platform A is possible for not consistently delivering a good hole penetration during soldering unlike platform B which get high probability for delivering consistent hole penetration.

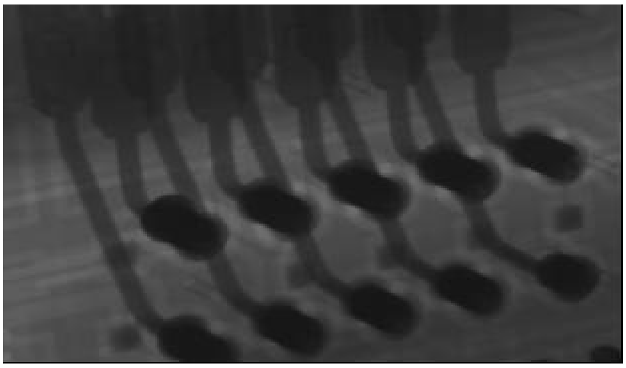

Figure 28. X-ray of product solder on platform A

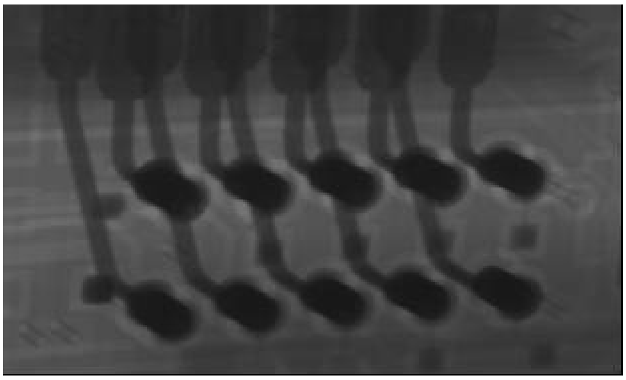

Figure 29. X-ray of product solder on platform B

Figure 28 is an example showing that pin 1 have <75% hole fill while the rest have a >75% hole fill while Figure 29 shows that all pin meet the requirements

Cross Section Analysis

Cross section shows that solder filling of all the joints for both platforms were good.

Fig.30 and Fig.31 shows that there are voids but still not exceed to 3-4 microns, which consider good and acceptable. Voids are holes in a solder joint. It can decrease electrical and thermal conductivity of the interconnection path and cause thermal failure. Outgassing in the plated through-holes during soldering may produce holes in the solder; another cause can be contamination of the surfaces. This can be prevented by improving board quality and clean surfaces of components. Pre-bake boards; increase soak time, or use nitrogen.

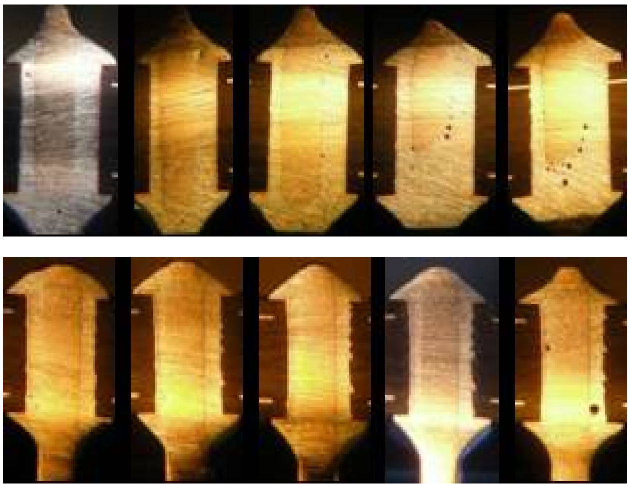

Figure 30. Cross section of product on platform A

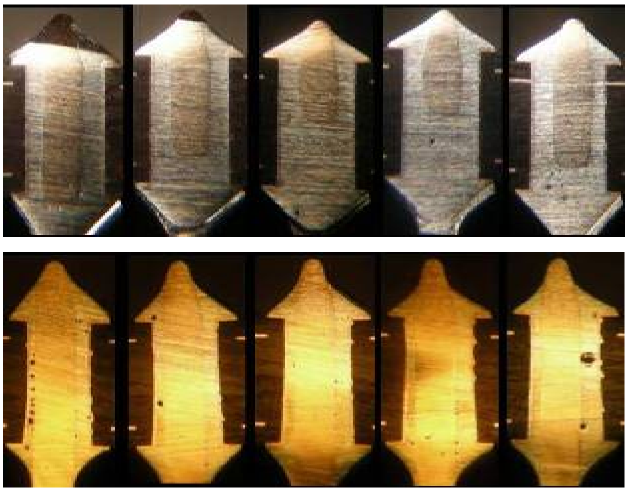

Figure 31. Cross section of product on platform B

COMMERCIAL COMPARISON

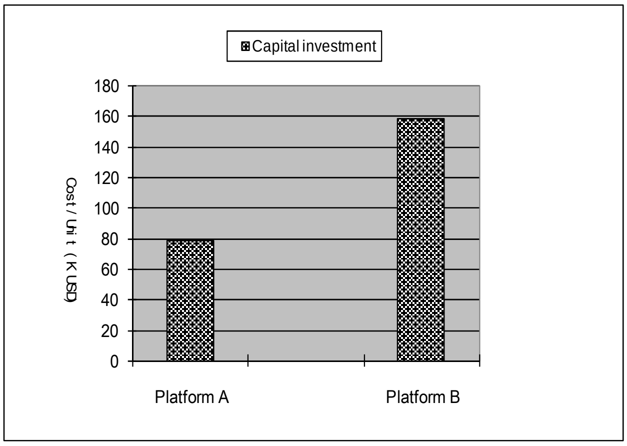

Figure 32. Investment comparison

Difference of capital investment between platform A and platform B as shown in Figure 32 looks attractive on manufacturing point of view but it is not recommended to use as base line in selecting a selective soldering that most fit on your product or application.

SUMMARY

Platforms design and material consideration are the most important factors to consider in selecting the best fit platforms for your product or application. The design will determine on how the platform can achieve the rest of parameter needed for the product. Reliability of samples that soldered on each platform reflects that either platform can able to meet good solderability.

Mass production data proves that platform B deliver more output because the soldering performance is consistent and stable compared to platform A which experience more stoppages during the evaluation

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