



Rework – The Hidden Phenomenon?

The recognition of the Rework and Repair process as an important factor in any electronics manufacturing facility has resulted in a mature approach to the Hidden Phenomenon. In an industry where the focus has been on achieving defect free processes, it was difficult to accept the existence of any rework requirements. Thus it remained hidden from view on the production floor as much as from engineering agendas. Companies promoted their strides towards the Six Sigma Goal where rework was becoming more and more redundant. Alas the truth behind rework is coming to the forefront and its acceptance as an integral part of the assembly process has reaped many improvements. Where will it stand in coming years? Well this article shall discuss many factors that play an important role and raise a few examples of the research being conducted into the Rework Process.

The Process

As with any soldering process, be it reflow, wave or hand soldering, the following critical parameters must be considered;

The surfaces of the metals to be soldered should be free of contaminant and oxide.

Flux* addition is optional depending on the condition of the metallic surfaces.

Heat is applied and dissipated on the metallic surfaces to be soldered.

Upon achieving the melting point temperature of the solder alloy, the solder wire shall start to melt onto the metallic surfaces. Upon reaching the wetting temperatures of the solder, an Intermetallic Formation occurs resulting in wetting of the solder joint.

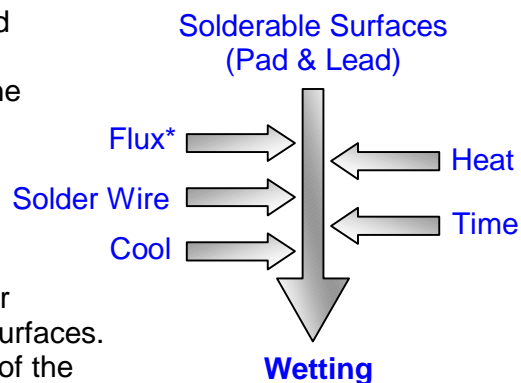


Fig. 1 Soldering Process

All of these parameters are conducted in relation to time and upon cool down a solidified, reliable solder joint is formed with good wetting characteristics.

Heat Transfer

Both conduction and convection techniques are present in all Rework processes and determining the most suitable technique for each task is important. The soldering iron is predominant in all rework tasks and there are many areas that require comprehensive understanding by the Reworker to achieve reliable solder joints. Tip contact must ensure adequate transfer of heat to the metallic surfaces being soldered, therefore choosing the correct tip contact is important. The tip should provide an adequate Thermal Bridge



between the metallic surfaces being soldered to allow for effective heat transfer.

Also an understanding of the Thermal Mass of the metallic surfaces is required. It is a common misunderstanding to drench a pad in flux because the solder isn't flowing. The usual cause of the solder not flowing is because of the high thermal mass of the pad or the component.

In Fig 2, an example of differing Thermal Mass is illustrated where Pad B has minimal Thermal Mass. Pad A has a significantly larger Thermal Mass as the ground plane acts as a heat sink dissipating the heat from the pad area..

Visually both Pads are dimensionally identical but differ greatly in terms of heat requirements.

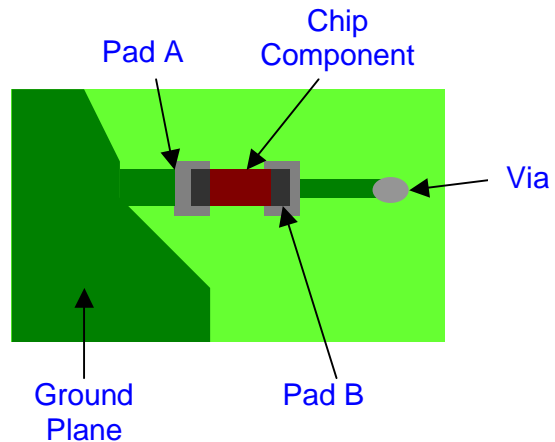


Fig. 2 Thermal Mass Requirements

Good Solderability of the pad and leads is becoming less of an issue with plating improvements and Just In Time materials handling processes. Caution is advised with Carousel Turntables that store replacement components in the rework area to ensure a First In First Out principle is applied.

Time – The Common Denominator

As rework is a value added process, time is a critical factor. The economic feasibility of reworking ten QFP100s on a PCA may warrant that the product is scrapped. Also the time taken by a Reworker to conduct a rework task is extremely important to achieve reliable solder joints. On a multilayered board with many areas of differing thermal mass, the longer the metallic surfaces remain heated, the increased probability of resulting damage incurred.

In a benchmarking project undertaken by EMTC, many issues highlighting the role to which training and experience are important factors in rework were quantified. The rework tasks were subdivided into the following categories with a selection of components chosen for conducting a time study analysis;

- Inspect and Determine Suitable Rework Procedures
- Component Removal
- Site Dress
- Alignment and Replacement Component Tack
- Resolder
- Clean
- Inspect



The rework procedure involved removal with Hot Air and replacement with a specific soldering iron tip.

An experienced Reworker (> 3 Years) with very little training was assessed in comparison to an inexperienced Reworker (< 3 months) who had received a high level of training. The inexperienced Reworker conducted each task in accordance with preferred soldering techniques and demonstrated a high understanding of the Rework process.

The experienced Reworker was deemed to have a high competency level but had minimal understanding of the Rework process. The experienced Reworker was capable of performing tasks that require a high level of experience much faster than the inexperienced Reworker. For example, to remove, site dress, realign and tack a SO20 took the experienced Reworker 55" as opposed to 1'46" for the inexperienced Reworker. In respect to the overall time taken to rework the component, the inexperienced Reworker took 2'14" and the experienced Reworker took 1'30". The time taken to complete the successive steps was near identical for both with the inexperienced Reworker 7" faster.

	Experienced (Time)	Inexperienced (Time)
Prep & Remove	25"	17"
Dress & Tack	55"	1'46"
Resolder	1'25"	2'01"
Clean & Inspect	1'30"	2'14"

Table 1 Summary of Time Analysis (SO20)

Training

More surprisingly from six different component types chosen in the study, the inexperienced Reworker completed four out of the six faster than the experienced Reworker. The main areas where the inexperienced Reworker took longer involved realignment of the component as detailed above. The ability of the Inexperienced Reworker to Do it Right First Time had a major influence on these results as the Experienced Reworker constantly was engaged in "Bad Habits". Having conducted a series of microsectional, shear and tensile analysis on reworked solder joints, the inexperienced Reworker proved to achieve greater solder joint reliability throughout.

From a training perspective, this quantifies the importance of training for any person involved in rework. It also raises the question of training for experienced personnel and the hand soldering techniques that they employ. Training should be conducted with a step by step approach where Solder Joint Quality, Solder Volume, Consistency, Rework Cycle Time, Soldering Iron Tip Contact and Control are the main assessment criteria.



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Hand Soldering Techniques

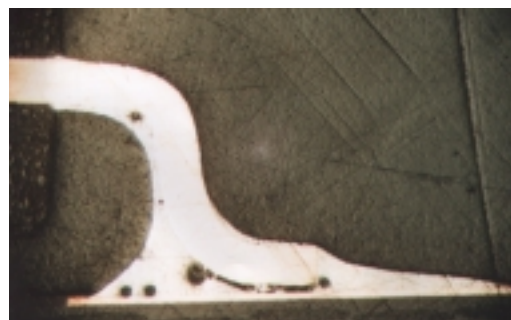
From training hundreds of Reworkers, it is a fair assumption that there is a preference for training personnel new to rework over experienced personnel. With experienced Reworkers they develop many 'speed soldering' techniques that have advantages and disadvantages in lieu of the techniques used. The first is "paintbrushing", a common problem where the Reworker returns to a perfectly reworked solder joint to retouch the solder joint numerous times. The associated heat cycles have many detrimental effects on the solder joint reliability. It is a subconscious action derived from a perceived view on what the ideal reworked solder joint visually should look like.

Most Reworkers that have such a habit are unaware of the fact that they are performing repetitive heat cycling of the solder joint and when questioned respond that they are making the solder joint more shiny?

Other techniques that raise questions involve the methods of transferring solder to the metallic surfaces. Dabbing is the application of molten solder from the tip into the joint area which is common with SM chip packages being reworked. Stroking is moving the tip in a stroking fashion while feeding solder wire into the joint area simultaneously, common for multileaded SMDs. Again these techniques don't allow for effective preheating of the metallic surfaces and are very difficult to control the solder volume to achieve consistency. Therefore they inevitably require further heat cycles to add or remove solder as required.

Hot Air Gun Issues

There is a more growing dependency in rework on Hot Air Guns. Using the HAG for removal and then using the old solder to resolder the replacement component results in many reliability issues. The lack of process control is a major concern as each Reworker may set the temperature and airflow to their preference resulting in an increased risk of damaging the PCB itself, inflicting extra heat cycles on neighbouring components, too high a heat or for too long a time. Also the reuse of old solder is well documented to increase the brittleness of the solder joint. Usually with resoldering of old solder, excessive application of flux is practised that leads to voiding in the solder joint. Also it is near impossible to achieve good wetting throughout the solder joint as illustrated in the microsectional evidence in Figure 3 and poor wetting in Figure 4.





Heat Cycles – Effect on Reliability

Heat affects the solder joint, component and PCB in many ways. The expansion/contraction action of the pads, internal layer damage, oxide formation and Intermetallic Growth are all aspects of Rework that reduce the reliability of the reworked product.

EMTC conducted an initial study of the effect of repetitive rework cycles to quantify the detrimental effects of excessive heat cycles on the reworked solder joint. Both Lead Free and Tin/Lead soldering were analysed with different numbers of rework cycles conducted on a selection of components. The study involved microsectional, shear and tensile analysis to quantify the reworked solder joint strengths. To maintain a realistic account of rework, there were no set parameters on the rework activities apart from an experienced, competent Reworker performing all the required rework tasks. Therefore a solder volume constant is not established and significantly impacts the results.

Eutectic Solder Rework

The assessment of reworked solder joints using eutectic Tin Lead solder invariably weaken with a single rework cycle but increase in strength after three rework cycles.

Table 2 illustrates the results of both Tensile and Shear tests conducted on the same components. All measurements are in Lbs.

		Rework Cycles		
Component		0	1	3
Tensile	QFP100	2.6	1.8	2.1
	SO8	5.7	3.9	4.9
	SO20	5.1	4.1	5.25
Shear	0805C	16.8	16.5	17.5
	0603C	6.1	4.0	3.8
	2012R	22.5	32.85	35.0

Table 2 Reworked Solder Joint Strengths (Eutectic SnPb)



Lead Free Rework

The same test structure was in place for analysis of reworked Lead Free processed PCAs. The SAC alloy was used throughout the process and in the rework assessment.

	Component	Rework Cycles		
		0	1	3
Tensile	QFP100	8.2	7.3	6.5
	SO8	>35	28.2	24.7
Shear	1206R	25.4	28.5	28.3
	0603C	11.1	12.3	12.1
	2520C	60.1	63.4	64.3

Table 2 Reworked Solder Joint Strengths (SAC)

Immediately it is apparent that the solder joint strengths from the Lead Free process are greater than that of the Eutectic Tin/Lead soldering process. The pattern shows that with tensile tests there is a definite reduction in solder joint strength associated with reworking gull wing leads for both Lead Free and eutectic Sn/Pb solder.

With the shear test analysis conducted on the Lead Free chip components it is fair to conclude that the increase in volume of solder has an impact on the results. This was not evident on the eutectic solder reworked joints.

Lead Free soldering introduces higher melting point temperatures for the alloy therefore giving rise to increased wetting temperatures. Reworkers will need to compensate for the higher wetting temperatures by ensuring effective heat transfer. The melting point temperature of the SAC alloy is approximately 217°C, that is a comprehensive increase from 183°C. The actual soldering with the SAC alloy had no apparent difference to eutectic Sn/Pb Solder. Tip temperature used for these trials was 700°F (≈373°C) to provide the extra heat required. The skill level and competency of the Reworker will be pushed to the limit with Lead Free hand soldering and it will not be a place for Reworkers who are having difficulties with eutectic Sn/Pb rework.

Probably one of the most unanswered questions in rework, the effect of heat and rework cycles on the solder joint there still remains a comprehensive amount of study to conduct in this area. The preceding tables give an indication but require comprehensive analysis to include SEM/EDAX and accelerated life testing.



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Conclusion

Rework is here to stay and still remains an enigma in many companies. With the correct equipment, training and understanding it is possible to consider Rework as a process with minimal variability. Expect to receive the same return as the size of investment put into rework because miracles never happen in this process. Hopefully this article will raise questions and discussion but is in reality an overview of the research that some companies are actively pursuing.

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A Guiding Influence in the Electronics Industry.



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