Soldering Process Improvement Of Critical SMT Connectors

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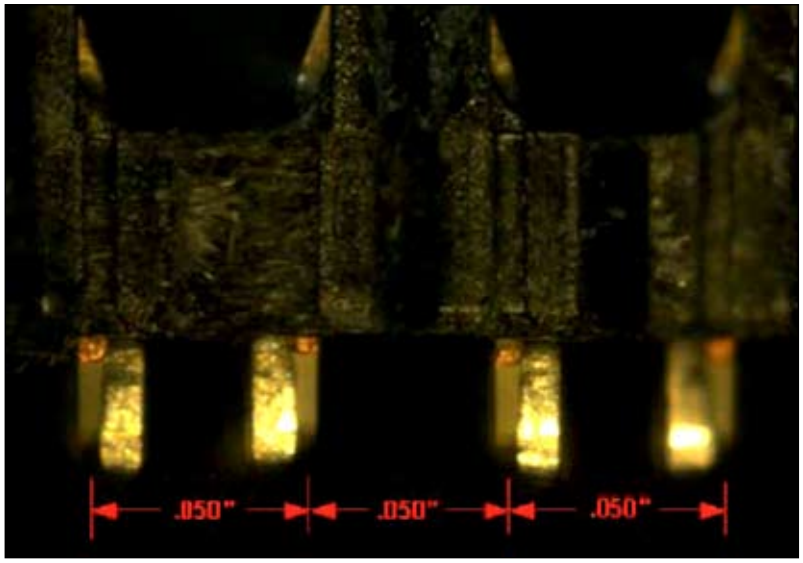
As Original Design Manufacturers (ODMs) adopt the use of finer pitch connectors with increased pin count on PCB assemblies, it becomes challenging for Electronic Contract Manufacturing Services (EMSs) to build with very low or zero defects. In this paper we take a look at experiments conducted with the aim of improving the SMT process with two connector types: Samtec's Searay (Aeam/Aeaf Series) connectors with 500 leads which have a unique solder charge design (leads are on a 50 x 50 mil pitch from row to row) and two Press-fit SFP Cages with different lead lengths, 1 with protrusion and 1 with no lead protrusion on an 18 layer fab (2.5mm thickness). Significant improvements have been obtained.

Connectors are commonly used in system interconnect more widely today. It is challenging to the PCBA process to have reasonable yields, and zero defects. A study was conducted to improve the SMT process with two types of connectors: Samtec's Searay (Aeam/Aeaf Series) connectors with 500 leads, and Molex and Tyco Press-fit SFP cages. With SMT and wave process improvements for these two connectors, the number of defects have been reduced significantly: less than 0.5% for Samtec's Searay connectors, and zero defects for Molex and Tyco Press-fit SFP cages. A 2DX with tilting angle detector was used to evaluate solder joints of the connectors.

Figure 1 – Solder charge location on adjacent rows – end view



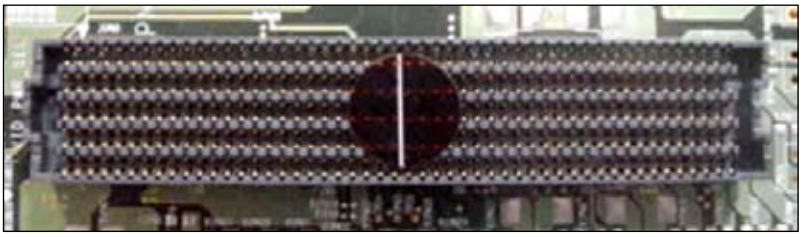
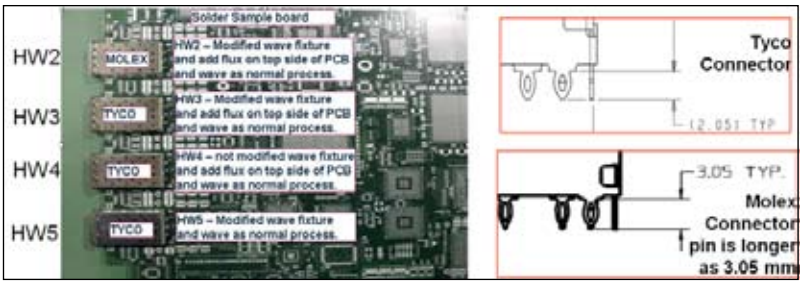


Figure 2 – 50 mil x 50 mil pitch: orientation alternates from row to row

Figure 3 – Connector type & process type



Components used

Samtec Searay connectors

The connector leads have solder charges which are offset, making the leads appear to be in pairs. The leads themselves are on a 50 x 50 mils pitch, but solder charges are positioned back to back because the lead orientation alternates from row to row. Figure 1 shows solder charge location on adjacent rows from an end view, and Figure 2 shows how its orientation alternates from row to row. The minimum stencil thickness requirement for the connector is 6 mils.

Press-fit SFP cages

The only variation is component pin length: 2.05 mm and 3.05 mm for Tyco and Molex respectively. Three new process designs of experiment (DOE) are described in Figure 3.

Improvement procedure and analysis: Samtec Searay connector

Flextronics's previous process to

Board	SMT	5DX
1	Pass	Pass
2	Fail	Fail
3	Fail	Fail
4	Pass	Pass
5	Pass	Pass
6	Pass	Pass
7	Pass	Pass
8	Pass	Pass
9	Fail	Fail
10	Fail	Fail

Table 1 – 40% of boards failed at SMT and 5DX

meet the connector minimum stencil thickness requirement of 6 mils was:

- Paste 4 mils solder to the board (note: from the time of paste printing, the assembly must be processed through the reflow oven within 30 min.)
- Load board into SMT carrier
- Hand print additional paste to the device using mini stencil
- Hand load connector to board
- Process through reflow with adjusted and approved profile
- Screen for defect visually and with 5DX/Dage
- Report out on any additional observations.

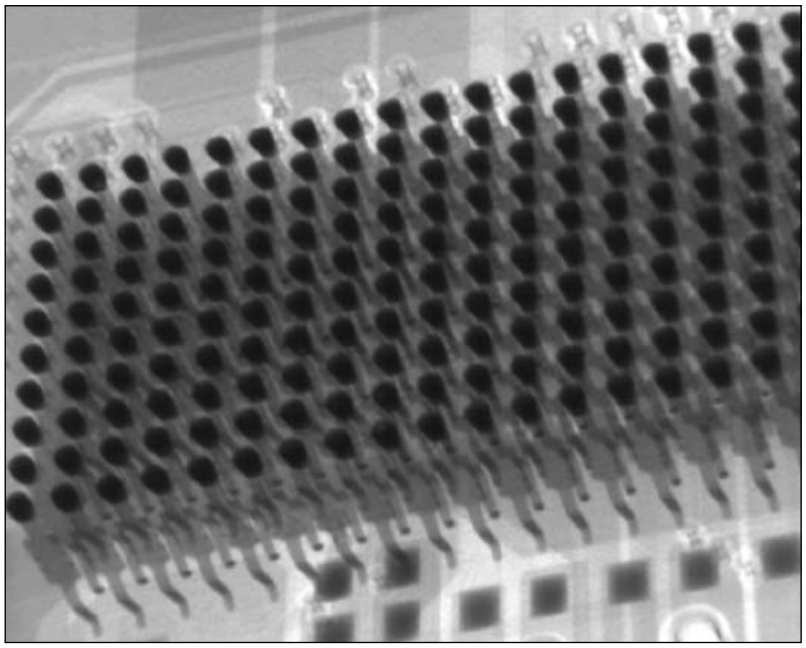
The solder is lead free: Senju M705 GRN360-K1-MK-VS Sn3Ag0.5Cu. The profile Peak Temperature is 231-233°C; Reflowing time above melting point, 220°C, is between 46-57 seconds. And soak time is about 99 seconds; Ramp rate is 1.75°C per second. However open defects for boards resulted. Table 1 lists data from 10 boards. Most of the defects are opens which is verified with Dage 2DX machine.

The main improvement introduced is the use of a 6 mil thick stencil with a 4 mil step-down thickness for other components. Stencil is stainless steel and laser cut. The stencil aperture is 35 mils, and its pad diameter is 35 mils. The stencil area ratio is 1.46, and aspect ratio is 5.83.

Item	Original Profile	Modified Profile
Temperature peak @ 220°C	231.1	243.17
Time (seconds) above @ 220°C	46	65
Soak Time (seconds) @ 150-220°C	99	100.3

Table 2 – Parameters for original and modified oven profiles

Figure 4 – 2DX images shown connector's pins have good solder joints



Lead free solder is the same as in the previous process. However the peak temperature was modified to 241-243°C. Reflowing time above melting point, 217°C, is about 65 seconds. The soak time is about 100 seconds with a ramp rate of 2.12°C per second. Table 2 lists the parameters of the oven profiles for the original and modified processes.

Figure 4 is 2DX images for the connector pins which shows good solder joints. The key operation is to find the right tilting angle to check solder joints with the Dage 2DX machine. With the new stencil (step-down 6 to 4 mils), the defects reduction went from 15% to less

Step	Process	Time needed (s)
1	remove connector from tape reel	10
2	inspect solder charge	10
3	place connector on fixture holder	15
4	align mini stencil of connector	20
5	print solder stencil	60
6	remove mini stencil	15
7	remove connector with solder pase	10
8	inspect solder paste and solder charge	30
9	install connector on board	10
	Total time needed	180

Table 3 – Time costs for previous process

Table 4 – Comparison of previous and current process

Stencil Type	Previous: 4 mils + mini stencil 4 mils	New: Step - down 6 to 4 mils
Total Connectors loaded	5648	1870
Defects %	15	0.50%
Total defective connectors	848	10
Total process time (second)	1,016,640	336,600
Total time added (hour)	282.4	93.5

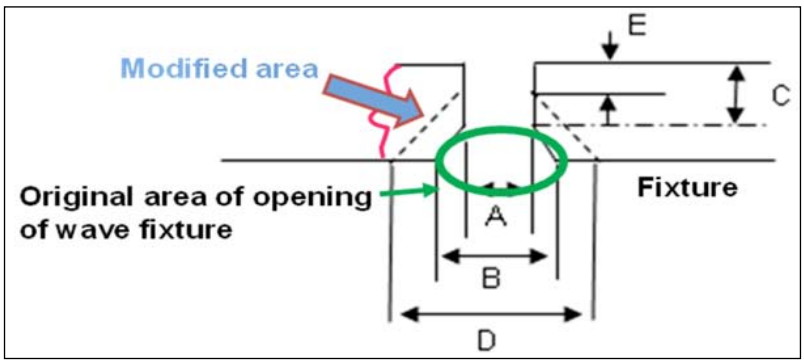


Figure 5 – Modified wave fixture

Table 5 – Original and modified wave fixture dimension

Original Fixture Dimension (mil)			Modified Fixture Dimension (mil)	
A	B	C	D	E
172.5	412.5	155	696.5	90

than 0.5%. The SMT process time reduction ($70/hour X 0.05 hour/board): represents a cost savings of about $6500 alone for six months. Table 3 lists time savings from the previous to the current process. Table 4 lists improvement of the current process.

Improvement procedure and analysis: Press-fit SFP cages

Because there were issues with Press-fit SFP cages failing mechanical drop test, the customer requested the addition of solder to the peripheral row of pins of the SFP cages for a stronger retention to the fab. These two different manufacturers of SFP cages have different lead lengths. The assembly uses a .093 thick fab, the Molex part has a .021 lead protrusion, and the Tyco part has no lead protrusion with this fab thickness, which is fine for the press-fit process, but the concern was getting enough barrel fill during the wave process to ensure part retention. It was not possible to make all pins have a good solder joint with a non-modified wave fixture, and wave as a normal process. Therefore, three new process designs were introduced (a. Modified wave fixture, flux added on the top side of PCB, and wave as a normal process for the two different vendors' components; b. Unmodified wave fixture and flux added on the top side of PCB and wave as a normal process; c. Modified wave fixture and wave as normal process). The three different process methods were used for the experiments (Figure 3). As shown in Figure 3, the Molex SFP cage is on HW2, and Tyco SFP cages are on HW3, HW4, and HW5. The wave fixtures were modified as Figure 5 shows; Table 5 lists the original and modified wave fixture dimension.

The wave process differences for HW2, HW3, HW4, and HW5 are as follows:

- HW2: Modified wave fixture and flux added on the top side of PCB and wave as normal process (Molex SFP cage)
- HW3: Modified wave fixture and flux added on the top side of PCB and wave as normal process (Tyco SFP cage)
- HW4: Unmodified wave fixture and flux added on the top side of PCB and wave as normal process (Tyco SFP cage)
- HW5: Modified wave fixture and wave as normal process (Tyco).

Connector Name	Process ID	Pull Force (lb)
Molex	HW2	45.6
Tyco	HW3	15.8
Tyco	HW4	19
Tyco	HW5	16.8

Table 7 – Pull Test results

With the new wave process methods, these connectors have good retention to the fab, and there are no defective pins for currently built boards. 2DX with tilting angle detector is used to check the solder joints of the SFP cages. Figure 6 shows the 2DX images of connector pins #10 and #11 for HW2, HW3, HW4 and HW5. There is no significant difference between solder joints for HW2, HW3, HW4 and HW5. In these images, the 2DX rotation angle is 105 degrees and its oblique angle is 52 degrees.

A Pull test was also used to examine the amount of force before solder joint failure, utilizing the Chatillon Digital Force Gauge - Model DFIS 200. The speed is 500 mil /second. Table 7 shows the Pull test results. The Pull test data also show that these three methods work well. HW2 and HW3 is the same method with different connector pin length from different vendors. It is no surprise that HW2 has almost 3 times full force as HW3 as HW2 has a longer pin (Figure 3). As a result of this process modification, there have so far been zero defects on several hundred boards that have been built with the HW2, HW3, HW4 and HW5 process.

This article is based on a paper originally presented at IPC APEX 2011

Figure 6 – 2DX images of connector pins (#10 & #11) for HW2-HW5