First Article Inspection Strategies

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Introduction
In these days of high mix low volume there is increasing pressure on the SMT departments of manufacturing companies to reduce changeover times and increase machinery utilization. An enormous effort has been taken within the SMT, Production Engineering and QA departments to ensure the setup of pick and place machines are accurate, and still issues of incorrect parts loaded onto PCB's exist. Each time this seemingly random event occurs there is enormous speculation as to how it happened and generally an additional control is concocted to supposedly correct this from "ever happening again". All this has done is added more wasted time in the changeover of each job on the SMT line.

What needs to happen is an entire re-think of the process of SMT line changeover and to use technology to assist and streamline this process. First Article Inspection Machines are available to ensure that incorrect set-ups are a thing of the past as well as speeding up the entire process so that the downtime on your expensive SMT lines is kept to a minimum. This study has been done in order to compare the standard manual processes used in normal CEM environments to the automated First Article Inspection (FAI) System assisted methods and the results are presented here.

In order to fully understand the process improvement aspects of the First Article Inspection System assisted methods a comparison of both processes is detailed below that highlight the drawbacks as well as the areas that are improved.

Manual First Article Inspection Method
The manual method described here is the most common method used in SMT areas within a CEM environment and is the one that was used by the company related to the study discussed later in this paper.

The PCB/First Article is built by the SMT machines and sent to the QA department for the purposes of checking the product assembled against the Bills of Materials (BOM) to ensure that the program contained in the SMT Loaders is correct as well as the parts are placed into the feeders in the correct locations. The steps involved in this process are described below:

The feeders with the parts installed on them are loaded into the SMT Loader into designated slots pre-established by either a manual method or CAD Conversion program specifically designed for this purpose. Normally there is a double check from QC or another operator to ensure that the correct parts are contained in the right feeders.

Normally the program that runs the Pick and Place machine is split into two parts, the feeder file and the program listing. The feeder file is the one that contains the locations of the feeders and the parts contained in them. The Program listing contains the X/Y/Z locations on the PCB. This data is normally automatically generated using the CAD Data supplied from the customer or engineering departments. This CAD Data shows the positions (X/Y) and the Reference Designators.

Once this is done the first PCB is then screen printed and populated using the SMT Loader. Normally prior to reflowing the PCB is initially inspected by the operators. This minor inspection is limited to IC's and polarised parts generally for correct values and direction.

After reflow the First Article is then turned over to the QA department within the SMT area for full inspection. To perform this function QA is required to search the PCB using the BOM, Loading Diagram (This is because most SMT PCB's do not have reference designators marked on the PCB) for each of the reference designators looking under a magnifying lamp or microscope to visually inspect the parts to ensure the accurate setup of the SMT Loader. The QA inspector must manually cross off the parts one by one until all parts are found and inspected. The SMT loader program is also crossed off to ensure that no additional parts are loaded that are not contained on the BOM.

This stage of the First Article Inspection Process is an absolute nightmare to ensure all possibilities of errors are checked out. The documentation that requires cross checking includes the Customers BOM, the BOM from the MRP system, loading diagrams, Feeder lists and Pick and Place files. This is in addition to searching under a microscope for the correct part locations. All paperwork must be checked against each other as well as the PCB in order to ensure that the Pick and Place machines are set up properly. This is an extremely tedious routine that can produce errors at so many levels.

The SMT loaders are possibly not run during this process as it could potentially be loading incorrect parts. Normally the SMT loaders start running once the major parts (IC's, capacitors, and any polarised parts) are checked. This is to minimise the length of downtime associated with the SMT Loaders. The rest of the parts are then inspected. When military or medical products are manufactured the SMT loaders must wait until all inspections are performed as these types of customers do not allow rework to PCB's and if incorrect parts were loaded then it would be far too costly to allow this to happen. The economic reality is that the machines cannot be stopped for this long and risks are taken every day and sometimes the gamble does not pay off and rework occurs.

Sometimes inspection aids are used in conjunction with these processes such as scanners (Mylar sheets with locations and polarities marked) that are overlayed on top of the PCB which indicate particular areas of interest and the feature (Location and Rotation data) to be inspected. These scanners can take significant time to construct and are generally made as aids to subsequent runs of the same PCB's. They are very time consuming to construct and are limited in their ability to located incorrect part quickly and reliably.

Automated First Article Inspection Method
The methodology used with an Automated First Article Inspection System is very similar to the conventional method described above however it is inherently faster and more accurate.

Using the Automated method the same process for setting up the Pick and Place machine takes place and the First Article is reflowed and turned over to QA for inspection. The system of inspection is markedly different in an automated system.

The First Article PCB is scanned into the system and the CAD data from the SMT machine that loaded the PCB is combined with the digital image of the PCB. The digital image is magnified to ensure that the markings on even the smallest parts are legible. The engineering BOM used to generate the Pick and Place loading program is loaded as well. This will cross check the Pick and Place file against the customers BOM to ensure that no extra, missing or changed parts exist.

For the first PCB ever inspected of this type all of the data on the BOM is stepped through with the image on the screen showing a greatly expanded view of the part being inspected. The operator does not need to worry about checking off parts in the system as the data contained in the BOM came from the SMT loader so it is 100% accurate. The location of the individual parts on the PCB is automatic as well because the X/Y coordinate data comes directly from the pick and place files. This enables the operator to concentrate on the visual inspection of the parts on the PCB. The combination of all data and image into a unified computer based environment makes the job of First Article Inspection very efficient and 100% effective.

Once the first PCB of this type is inspected it is saved as a sample for future reference. Any subsequent batches of PCB's of this version will automatically be compared to the sample stored. This process will ensure that no parts have been added or deleted, moved or rotated. This guarantees that once a PCB has been manufactured once, all subsequent runs will be the identical providing unparalleled consistency in manufacturing.

Case Study
The case study introduced here was performed on a CEM in Sydney, Australia that introduced an automated First Article Inspection System several years ago. This contractor is a medium sized manufacturer that has 5 SMT lines including two MyData standalone systems, two Yamaha lines and a Juki line loading approx 5 million parts per month. They do not own any AOI systems and perform only functional testing (not ICT) on product manufactured. This variety of equipment is to accommodate all types of short runs of complex PCB's. As is common in the United States most CEM's in Australia are geared up for this as most large quantity manufacturing runs are being sent to China. This has required the SMT department to focus heavily on reducing downtime due to changeovers between runs of PCB's. This CEM performs a full changeover of every SMT line at least 2 times a week.

Prior to the installation of the automated system a review of all problems encountered that was attributable to the SMT assembly process took place.

Random parts missing/incorrectly loaded (skewed, tombstoned, etc) – This is when parts are randomly missing or incorrectly loaded on PCB's with no consistency. These were attributable to the Pick and Place machines and handling of the PCB's prior to reflow. These types of defects would only be corrected with an AOI. Soldering defects – These include solder shorts, cold joints, etc which are mainly attributable to the screen printing process.

Incorrect parts – These are parts that have been loaded incorrectly due to incorrect set up of Pick and Place or due to swapping an incorrect reel during the batch. These are the main area of concern that an automated first article inspection system will alleviate.

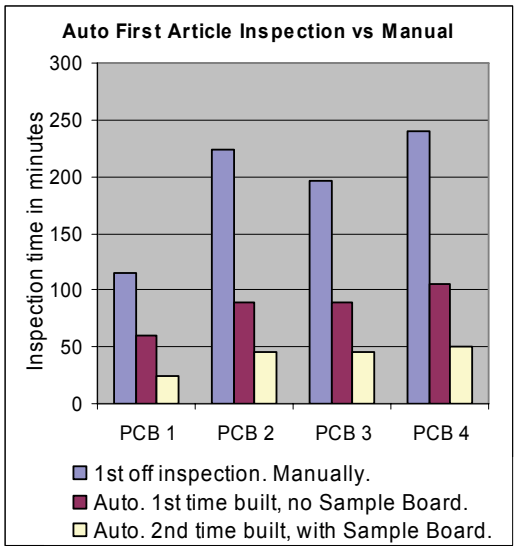
The first two categories can be controlled with an AOI system in place however it was deemed that AOI is not suitable or cost effective at the level of manufacturing that this CEM is involved with. Five AOI systems would have to be implemented at very high expense involving hundreds of thousands of dollars. In addition to this, the programming time required to keep up with short run, high complexity assemblies would be prohibitive rendering the AOI option not feasible.

The final category is the one of most interest as there are a large percentage of defects pertaining to these types of problems and that there is an economical solution to these. The implementation of an Automated First Article Inspection System also reduced the changeover time associated with the SMT lines.

The problem of the incorrect reels of parts inadvertently loaded onto PCB's appears on the surface to be a fairly random event however this cannot be further from the truth. If a company produces 5 million parts a month on PCB's (medium contract manufacturer levels) the first article inspection process would be checking approximately 10,000 parts per month. This is because only the first PCB's are checked in this process. If human error leads to be 1 problem in 1,000, which would be considered extremely good, there would exist 10 potential problems each month. Using the manual method, given that the probability of inspecting 100% of parts is low and likely to be only 70%, then this would reduce this to 3 problems per month. If each of those 3 problems were associated with reels of 5000 parts, which is common to reel sizes, then 15,000 parts are possible to be incorrect every month. As entire reels are unlikely to be used up on any given run is low prior to someone finding out that the parts are incorrect then the figures are likely overstated by potentially 80%. Even at these levels there would exist 3,000 parts incorrect each month on average.

The reason that Automated First Article Inspection Systems are not utilised is that there is a belief that these errors can be traced backed to things like not checking the reels in machines. So the common mistake is to have another person verify the set up which appears to work and everyone feels the problem is solved. Being a manual system this is a bandaid solution and the problem resurfaces. The fact is that with every manual system there is a level of human error and when we deal with vast quantities of potentials for error eventually one occurs. It is like attempting to inspect quality into a product, it does not work, it is critical that it is built in to it.

Besides the stated QA reasons for implementing Automated Systems, there is a monetary one in that the manual process is a very lengthy process. As shown in the figure below four PCB's were sampled with respect to the time it takes to inspect them 100%. The PCB's used for this chart contain a variety of SMT parts on them between 300 and 600 components on each.



The first column indicates the time it took to inspect manually. The next two columns is the length of time it takes to inspect the same PCB's using an automated system. Because of the way the automated systems work it is much faster to inspect subsequent runs of the same PCB as the system compares the PCB being built now with a stored sample manufactured before. There are incredible savings in time achieved especially if you consider that the Pick and Place machines are not producing during this time.

If these times shown are extrapolated out to take into account all of the First Article Inspections performed in our test case the results are outstanding. If you take the average of the 4 PCB's discussed being 3 hrs per changeover the saving would be $960/week @ $40/hr.

Manual First Article Inspection Time average	3 hrs
Automated Inspection Time average	0.6hrs
Labour rate per hour	$40/hr
Changeovers per week (5 lines, 2 per week)	10
Time spent on manual inspection	30 hrs
Time spent on automated inspection	6 hrs
Time saved per week	24 hrs
Dollars saved	$960 per week

This does not take into account the savings made in Pick and Place downtime that would be substantially more than the figures stated above. Lost Opportunity Cost is the cost per hour that the SMT Pick and Place line earns per hour if it were producing product instead of waiting for First Article Inspections to complete. If the lost opportunity cost is accounted into the equation then it would bring the total dollars saved into thousands each week.

This particular CEM deals mostly with high end medical and military equipment and the QA requirements are such that the SMT lines cannot begin loading product prior to completion of the first article as rework is not an option with these types of customers. Also the CEM was reaching capacity for the SMT output they were at the crossroads of either to reduce changeover times or purchase additional equipment. The implementation of the First Article Inspection System provided the CEM with an additional 24 hrs per week of SMT throughput allowing them to put off buying expensive new SMT equipment.

An additional use for the automated FAI system is that a sample of each line is taken once every 2 hours and put through the FAI process to ensure that no incorrect reels have been replaced in the SMT loader. This can happen when restocking feeders in the middle of production.

Conclusion

In these days where there is ever increasing pressure to produce short runs of high complexity PCB's faster changeover times are high on the agenda to save time in manufacturing. Every hour of downtime is costing big money.

Utilising an Automated First Article Inspection System the SMT section has the ability to confidently assure consistent output. It has been stated that all functional areas within an electronics manufacturing environment must have the ability to verify their own output quality. This is impossible to achieve using manual inspection methods. Automated methods will enable the SMT department to verify its own output at minimal expense.