Test Equipment and Methods - Test automation:
PCBA Automated Testing Traceability and Fault Tracking (RFID) System

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Abstract
As a PCB board manufacturing organization for high end customers, it becomes our responsibility and requirement to produce very high quality (Class III) products and to ensure that only faultless items reach the customer.
The most crucial thing is to test the items with maximum test coverage and keep the traceability records of electronic components and to keep track of all operations performed during manufacturing process.
No matter how good we are producing a product, every now and then a defect will be produced. A small percentage of failure is always expected. But what if your board is going to be used in some critical applications? If that board fails and reach the customer, you could be looking at huge costs in terms of reputation and recreating it. In that case, it becomes necessary to have powerful repair solution which can track the defects produced during product testing and help production to repair them, in an efficient manner.
To meet all these requirements, a system was designed and developed which automates the assembly testing and repair process and keeps track of all the manufacturing history of produced board’s.

Introduction
In addition to just delivering the finished products, it becomes essential for manufacturing industry to provide the complete manufacturing record of exactly what has happened to any of the product during the operation’s. It is the key challenge for them to produce the faultless product with zero tolerance especially, when their product is going to be used in critical applications.
To overcome the challenges like maintaining the traceability record’s, producing faultless board’s and shipment to customer with zero defect, we have implemented a system in our PCBA production line.
This document explains the main features of this system which also makes smart use of RFID (Radio Frequency Identification) technology to keep track of the boards. The goal is to eliminate the shipment & use of faulty boards.

System Overview
The system is known as Digital Fault Tracking System (see the figure 1 for system process flow). As the name suggest, the purpose of this system is to monitor and track the defect’s in PCB board’s encountered during manufacturing.
This DFTS system comprises of three major parts:

1. **Traceability**
2. **Testing**
3. **Repairing**

**Traceability**
To provide the manufacturing records to our customer, a traceability system was implemented which performs the traceability of our PCBA board’s for following

1. **Traceability of components**: this we do to be able to trace all the electronic component’s linked to serial number of pcb boards on which they are mounted. The traceability data includes
   - Supplier name of the component
   - Component reference/location on the board
   - Date code and lot code of the electronic components
   - Records of all the mechanical placements of electronic components

2. **Traceability of gluing process**: As we are manufacturing the pcb boards which combine surface mount and traditional through-hole, it is necessary to use an adhesive to attach devices to the underside of the mixed technology board. Such types of gluing processes are very critical in nature and required to be monitored very carefully. The system is able to monitor and provides the following records for such gluing processes
   - Supplier name, manufacturer reference, date code and batch number of the adhesives used.
   - Temperature profiles
   - Management of moisture sensitive components and track the remaining floor life.
   - Operators of such critical operations.

3. **Traceability of operations**: In order to improve the performance of operation’s, the system monitor’s all the operations performed on pcb boards as follows
   - The system ensures that all the production steps are followed.
   - Collect the data from all manual stations & records all the failure occurred during the operations
   - Able to restore production history of all the board’s.

**Testing**
In order to achieve maximum test coverage, every test stage is automated with world class test equipment’s and arranged in such a way as to be able to test a board with minimal human interaction. Our PCBA testing process is divided in three major parts (See figure 2 for PCBA test hierarchy).
1. **In-process testing:** They are the checks being performed during the production process of pca boards for the purpose of monitoring and if necessary, to adjust the process to assure that the boards conforms to its specifications. It includes the following:
   - **Solder Paste Inspection (SPI):** World’s best class SPI equipment is installed to inspect the soldering status of pca boards in 3-dimensional form. Through this testing we are able to automate the inspection of the pcb board’s soldering status by comparing and analyzing the height and volume of solder with 3-dimensional information of various images taken by high resolution camera.
   - **Automated Optical Inspection (AOI):** An automated visual inspection is performed on pca boards using advanced technology machine’s. A high resolution camera scans the pca boards for variety of surface features defects such as scratches and stains, open circuits, short circuits, thinning of the solder as well as missing components, incorrect components, and incorrectly placed components.
   - **Manual Visual Inspection:** In order to detect fault at the earliest possible opportunity, manual inspection of component placement is performed just after the surface mounting (SMT) process is over. This inspection is incorporated at several stages just to ensure everything is covered and inspected visually.
   - **X-ray:** During the process, many components, such as ball grid arrays, have connections underneath the component which are not visible. They cannot be inspected through manual or automatic inspection machines. To test such types of component’s, X-ray equipment is installed which is able to identify the defects with these components such as cracked solder joint’s, Excess flux, BGA separation etc.

2. **Bed of nails:**
   At the end of the PCB production process we electrically test every multilayer pca board. Using this type of testing we check each board to ensure that there is no open circuits and pins does not short to each other. The advanced equipment’s in our PCBA production line can test the multiple boards at a time to increase the throughput and efficiency. It includes the following
   - **Flying probe testing:** Flying probe tester is a fixture less test system which uses motor controlled test probes to make contact with the board to be tested. They are easy to setup as no fixture is required for this.
   - **In circuit testing:** It uses a bed-of-nails test fixture to access multiple test points on the PCB’s bottom side. With sufficient access points, ICT can transmit test signals into and out of PCBs at high speed to perform evaluation of components and circuits. This system is faster than the flying probe testing. This we use where high throughput is required.

3. **Computer Aided Testing (ATE’s):**
   Once the board is assembled, it goes to the final testing stage where the functionality of the board is tested through customized test application. To achieve the final testing, we have designed several test towers equipped with various measurement instruments (see figure 3) & fixtures (see figure 4) which make the software application able
to communicate with the board under test to send the commands to it and read out the different measurement readings.

Figure 3: Test Tower

Figure 4: PCBA Test Fixture

The software application is develop in house which allow production line operators to perform following types of operation along with functional testing (see figure 5 for application layout):

- **Boundary scan testing:** Boundary Scan (IEEE 1149.1) is a method of testing interconnects (tracks, pin-soldering, etc.) on a pcb and sub-blocks inside an integrated circuit. It is very useful in determining the manufacturing defects, such as "stuck to 0", "stuck to 1", "shorting" and "open", in a BS-compliant 'populated PCB'. As now a days when PCBs are multi-layered and ICs are highly miniaturized (e.g. BGA), Boundary-Scan gives us a capability to have a high test-coverage without adding any physical probes (unlike ICT). We use boundary-scan testing for building reliable high technology pcb boards with a high degree of testability.

- **Programming:** For uploading and programming firmware files to the board under testing, we have developed VI’s(Virtual Instrument’s) using latest technologies like Lab view, Test Stand which can communicate with the board under test via different protocols (over secure shell). These VIs are general purpose which can be easily configured and reused for the scalability.

- **Functional Testing:** Here we developed and implemented an application that checks the complete functionality of board. Once the board serial number barcode is scanned, the application checks the database if any of the previous operation stage is still needs to be performed or not. In case of any pending status, it doesn’t allow the user to continue further testing. This way it eliminates any chances of skipping any of the operation stage during manufacturing. After checking the status of previous operations, application executes the test sequence. If the board is passed in functional test, it is directly forwarded to the packing stage. If the board is failed, an rfid tag is affixed to it and scanned through the RF scanner which interlinks the rfid tag number with the board serial number and saves the information into the database. After that board is forwarded to repair stage.
Not only does the application provide the real time feedback to test engineers, but it also provides the quality department with the powerful statistical reports and the data they need (for statistical report see figure 6).

It stores the results of the final test of each board to central server and performs the statistical analysis for traceability, trend tracking, and other quality studies like first pass yield report etc. It helps in process improvement by provides a picture of how our test systems and processes (during board testing) are performing over the time.

**Repairing:**

In order to identify the faulty boards, we used to attach the paper tag to them (see figure 7 for board identification with paper tag). The major issues we faced with paper tags were:

- The paper tags introduced the risk of electrostatic damage of pcb boards as they were not ESD safe. We were bound to invest more in the paper tags to make them ESD safe.
- Paper tags put the burden of recurring cost due to use of new tag with every faulty board.
With keeping such types of things in mind, we came up with an idea to replace the paper tags with ESD safe reusable RFID tags (see figure 8 for board identification with RFID tags).

**What is RFID and why we use it in our system?**

Radio-frequency identification (RFID) is an automatic identification method using radio waves. It is used to transfer data in a wireless environment for the purpose of automatically identifying and tracking tags attached to the objects. The tags contain electronically stored information which can be read by RFID reader using radio waves. When this tagged object is presented in front of a suitable RFID reader, the tag transmits the data to reader via reader antenna. The application can then use this unique data and perform the variety of actions on it. Use of this technology in our system automates the board identification on the shop floor.

**Advantages of using RFID tags:**

We replace the paper tags with RFID tags as they have lots of advantages over paper tags. Some of them are listed below.

1. RF tags are cost effective in terms of reusability while paper tags are expensive due to recurring cost.
2. It is possible to identify the board, automatically with RF tags, but for paper tags it is not possible.
3. RF tag’s save the production time as less human interaction is needed for identifying the boards.
4. RF tag’s we use for our system are ESD safe while paper tags are not.
5. It is possible to rewrite the information on RF tags but in case of paper tag, we have to use new paper tag for rewriting the information.
6. There is less wear and tear with RF tag but paper tags are more prone to it.
7. More information can be written on the small size of RF tags while paper tags are restricted to the information size.
8. Chances of error are quite low as everything is stored on central server linked to RF tag number but in case of paper tag chances of writing wrong information and losing it are more.
9. Automation is possible with RF tag but with paper tag it will be manual always.
10. Multiple RF tag can be identified at a time but for paper tags we need to check them one by one, manually.

**How System Works:**

Once the board gets failed at testing stage, an RFID tag is attached to it and linked with the board serial number. When the repair technician scan the rfid tag attached to the faulty board, repair application display’s the test & repair history of that board along with other useful information like graphical pinpointing of fault areas, repair turnaround times etc. This type of information is very useful for the technician while doing the repairing work. While doing the repairing, technician logs his repair action into the database with the use of repair software. After that software links this information to the rfid tag nr in the database (see figure 9 for application layout).
After all the boards have been repaired, technician puts them on a trolley. Normally, this pcb carrying trolley is accessible to everyone on production floor. Unintentionally, one may put the unrepaired board on this trolley or in short, chances of mixing of repaired board with unrepaired boards are very high. For the small quantity of boards, it will not be a big deal for the technician to filter the faulty one, but assume if we have hundreds of board on a single trolley. The operator may come into the situation where he gets confused if all the boards in trolley have been repaired successfully or not?

To filter them out, he will have to manually check each of the board which is very time consuming. To get rid of this type of situation, we designed an application which can radio scan all the board’s on trolley in one go(see figure 10 for application layout).

The trolley carrying all the repaired/unrepaired boards has to be passed through a scanning gate where RF reader is installed. The system scans all the RFID tags attached to the boards on trolley. For each of the identified tag, software queries the database to get the repair status of each and every identified board. As soon as any unrepaired board is found, system alert’s the technician about the same. Unrepaired board is removed from pcb trolley and sent back to repair stage.
In this way system is capable enough to physically identify the repaired board’s and eliminates the chances of getting mixed with the faulty one.

**Benefits of the System:**
- Automatic identification and tracking of faulty boards using radio frequency tags.
- Repair turnaround time calculation per board.
- Maintain the traceability records of electronic components in terms of supplier, expiry date, lot code etc.
- Maintain the traceability records of every critical operation.
- Cost effective system with reusable RF tags.
- Operation interlocking eliminates the chances of skipping of any operation during production.
- System performs statistical analysis on the test and repair data which provides the clear view of system performance and alert in case of deviation from the standards.
- Graphical pin pointing of fault areas on board gives the clue about most suspected faulty area of board’s during repairing.
- Tracks first pass yield & display work in progress (WIP).
- Centralized data storage with online detailed reports.
- All the applications are developed using latest technology which can be reused and reconfigure for increasing the efficiency.

**About The Author:**

Mr. Thaneshwar Jaglan received a *Bachelor in Engineering Degree in Electronics and Telecommunication* from *University of Pune* in 2003. He joined *Barco Electronic System Private Limited, Noida* in 2006 and currently working as a *Senior Software Engineer* in *Test Engineering and Industrialisation Department*. He has a better understanding of software development using latest technologies like Microsoft.Net & SQL and is responsible for development of automated test solutions to support Barco Production.

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