

Controlling Moisture-Sensitive Devices (MSDs) for Double-Sided Reflow Applications

Michael Blazier
Delphi Automotive Systems
Kokomo, Indiana, USA
michael.w.blazier@delphiauto.com

André Corriveau
Cogiscan Inc
Bromont, Québec, Canada
acorriveau@cogiscan.com

ABSTRACT

Moisture-sensitive devices are commonly used in the industry for many different applications. These components require special handling procedures that must conform to IPC/JEDEC standard J-STD-033 in order to prevent them from absorbing too much moisture prior to reflow. Otherwise they might cause a failure at test or even worse, a latent defect that will cause an early failure in the field. The guidelines of J-STD-033 are very challenging to implement using a manual tracking system. With the advent of double-sided reflow applications, some design limitations can force the use of moisture-sensitive devices on both sides of the board. It is then necessary to monitor not only the components that are placed during second pass prior to second reflow but also the components that were placed during first pass since they continue to absorb moisture between first and second pass. What was already very challenging can become almost impossible to do using a manual tracking system.

This paper explains how this issue was solved by the design and implementation of an automatic tracking system for moisture-sensitive devices during first and second pass. The foremost objective of the system is to avoid processing components that have exceeded their allowable limit through the reflow process during first and second pass. This is achieved by automatically tracking each reel or stack of trays from the time they are removed from their original dry bag until all parts are placed prior to reflow and also by tracking the first pass boards until they go through the process in second pass. The automatic system made this possible while maintaining an efficient operation by providing real-time status of the materials and advanced warnings of expiration for decision making.

Key words MSD, J-STD-033, Double-sided reflow

BACKGROUND

Moisture-sensitive devices require special attention during the assembly process. These devices absorb the atmospheric moisture when removed from their moisture barrier bag, which accumulates at the critical interfaces between the die, leadframe and molding compound. When

these components are exposed to reflow temperatures, there is a rapid increase of the vapour pressure inside the package, which can cause internal damage. At best, the damage will cause the device to fail and will be caught during electrical testing. But because these defects are typically latent, some will pass electrical testing and escape to the field.

To protect customers from the possibility of defects due to IC delamination caused by excess moisture, Delphi Delco Electronics Systems factories track exposure in accordance with IPC/JEDEC J-STD-033. Although the guidelines for storage and handling of MSDs are clearly defined in the IPC/JEDEC standard, they are quite challenging to implement. Users will typically err on the conservative side of J-STD-033, which can result in scrapping components that may not have seen their maximum exposure. A typical method is for assembly operators to attach a label to the component reel as soon as it is removed from its moisture barrier bag, filling in the date and time. Until all the components on the reel have been used, date and time will be recorded on the label whenever the reel is placed into a dry cabinet or removed from the dry cabinet, tracking the remaining allowable exposure time.

The dual reflow process has helped Delphi increase product functionality, reduce cost and space requirements for circuit boards. But moisture-sensitive components mounted in the first reflow process continue to absorb moisture, and can be damaged by the second reflow if their exposure limit is exceeded. Lacking a simple system for controlling the exposure time of components mounted to boards, it was necessary to sharply limit the use of moisture-sensitive components on the first reflow side.

However, layout and interconnect issues may require moisture-sensitive components on the first reflow side. Capital, space, and product volume may dictate that the same surface-mount line be used for Reflow Side 1 and Reflow Side 2, precluding a quick flow-through that could use simple Exposure Time accounting.

SHORTCOMINGS OF A MANUAL TRACKING SYSTEM

With double-sided boards having MSDs on the first side, the complex issue of tracking the life of the components only becomes more complex. Since the first reflow does not count as a bake, the clock of exposure time continues to run until the second reflow is accomplished. The first issue that comes to mind is how to assign the Remaining Exposure Time to a specific board. The components in a reel all have the same Remaining Exposure Time, because they are the same Moisture Sensitivity Level and were removed from their Moisture Barrier Bag at the same time. A single label speaks for all the components on the reel. But once the components have been mounted to the first side of a dual reflow board, it becomes necessary to assign a remaining exposure time to that board. The logical way to do this is to assign to the board the Remaining Exposure Time of the component with the least value on the assembly line at the time the board is produced. Following is one possible way to implement this type of tracking using a manual tracking method:

1. Look up the Remaining Exposure Time of each component active on the assembly machine(s). Select the shortest; this is the Remaining Exposure Time of the boards being assembled.
2. Label the containers into which the boards are being loaded with the Expiration Date and Time
3. When a reel (or tray) is changed on the assembly machine, review the Remaining Exposure Times of all components. If the shortest Remaining Exposure Time has changed as a result of the reel change, pause the line or insert a marker board into the stream to indicate the new Expiration Date and Time.
4. When the pause or marker board reaches the exit of the reflow oven, start a new container, marking it with the new Expiration Date and Time.
5. Use a FIFO system for moving boards into the second reflow. Consider the Expiration Date and Time when scheduling production. Schedules may have to be adjusted to ensure that all boards complete final reflow before Remaining Exposure Time reaches zero.

Although possible on paper, this scenario typically cannot be implemented in real life manufacturing. It is too work intensive and of course prone to human errors. Also, Step 1 cannot be achieved easily since the information on the label of the reel is difficult to access when the reel is in place on the pick & place machine. When using JEDEC trays, the problem only gets more complicated since there is no practical way to affix a label on the tray.

Using the above procedure, the Remaining Exposure Time is assigned to a batch of boards depending on the set of components present on the assembly line. Ideally, the Remaining Exposure Time should be assigned to each individual board to facilitate tracking. This is only possible if each board possesses its own unique identifier. But the task of recording the Remaining Exposure Time manually

for each board is huge and not practical in a high volume environment.

Even if all the boards or batches of boards are identified with their Expiration Date and Time, it is quite difficult to track and queue all the boards or batches manually between first and second pass based on expiration priorities.

OBJECTIVES OF AN AUTOMATIC TRACKING SYSTEM

Faced with implementing the arduous dual-reflow exposure accounting system, Delphi evaluated Cogiscan's MSD Tracking system. This product is already a solution fully compliant with J-STD-033 that provides real-time tracking of all MSD's from the time they are removed from their dry bag until final reflow. But it offered only single-reflow capability. In order to develop the capability to track and control boards during the first and second reflow, the following objectives were set for the system:

- Facilitate the implementation of J-STD-033 requirements for limiting exposure of Moisture-Sensitive Devices mounted to Single and Dual Reflow circuit boards.
- Adjust allowable exposure time according to the actual ambient factory temperature and RH, according to the requirements of J-STD-033.
- Maintain a database of:
 - Component part number, MS Level, Bake-Out Time/Temperature
 - Sub-assembly part number, Dual or Single Reflow, MS Level, Bake-Out Time/Temperature.
- Assign a Remaining Exposure Time (RET) to a board serial number during first pass according to the RETs of the components placed on it.
- Avoid baking first pass boards by planning for enough Remaining Exposure Time to go through second reflow.
- After the first reflow, form into a class board serial numbers that have the same product part number and RET.
- Display the status of all active components and boards during assembly in first and second pass.
- Provide alarms to prevent MSDs from being placed on subassemblies if their RETs are insufficient to complete subsequent soldering operations. When appropriate, stop production on the line to avoid building product outside of specification.
- Provide alarms to prevent subassemblies bearing MSDs that have exceeded their allowed moisture exposure from receiving additional components, and from being subjected to soldering processes. When appropriate, stop production on the line to avoid building product outside of specification..
- Maintain an historical database of past transactions

The solution that was designed and implemented can be broken into three basic elements; Material Identification, Data Capture and Process Control.

MATERIAL IDENTIFICATION

The definition of a proper material identification methodology is the foundation for the MSD control system. The IPC/JEDEC standard requires that a moisture sensitivity label be placed on the outside of the moisture barrier bag. However, when the individual trays and reels are removed from the bags, this information is lost unless it is transferred to the tray or reel. In order to automate the tracking of the components it is mandatory that some form of automated identification element be attached directly to the lowest-level container that is used to handle the parts on the manufacturing floor. The use of a barcode label is possible on reels but cannot be envisioned as a global identification method since many moisture-sensitive devices are packaged in plastic trays compliant with the JEDEC/EIAJ standard outline. It is also important that any identification method be fully compatible with the equipment and processes that are associated with the trays and reels. For these reasons, the Radio Frequency Identification (RFID) technology was chosen for the application. RF tags are passive electronic devices that can be read and updated when placed within the range of a reader antenna. One clear advantage of the RFID technology is that the tag can be made in various shapes to adapt to the item being tagged. The solution to tag reels is in the form of a thin disc of 20 millimeters in diameter by 1 millimeter in thickness. The disc is attached to the reel by placing it in an adhesive pouch. Since the discs can be reused several times, the pouch is designed with an opening for easy removal of the disc when the reel is empty. The tag design for the JEDEC trays is in the form of a reusable spring loaded plastic clip that can slide over the hook-shaped tab at each end of the tray. Both tag designs are compatible with the respective bake processes set forth in J-STD-033 (40C for reels, 125C for trays).



Fig 1: SmartDisk and SmartClip



Fig 2 : SmartDisk on reel

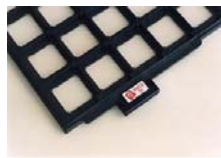


Fig 3 : SmartClip on tray

Each RF tag contains a unique identifier that is used to track and recognize the specific container. Another significant benefit of RF tags is that they contain a programmable memory that can be used to store identification and process

data directly on the material. This means that the same tags can take full advantage of a networked database in a closed-loop system, and can also be used with a stand-alone reader and to transfer data throughout the supply chain.

Typically, the tags are initialized in the system when components are released from stock. The initialization process is quite simple and only requires the entry of the part number and lot number for the components. Usually this information is on the sealed bag and it can be typed in or scanned in using a barcode reader. When a new part number is entered for the first time, the system will prompt the operator to enter the sensitivity level and component body thickness. This information is kept in the database and used to apply the rules of J-STD-033 correctly.

The other element of the material identification methodology is the PCB serialization. Delphi Delco Electronics Systems choose to use barcode technology. The labels contain a unique serial number and are applied to the PCB prior to the screen printer in first pass. The labels are designed to withstand the reflow temperature in the oven.

DATA CAPTURE AND REAL TIME TRACKING

After defining the material identification methodology, the next challenge was to design an infrastructure to capture the data and keep track of the physical location of the materials and real time status of the Remaining Exposure Time. The heart of the system is the Local Control Unit. It is a small footprint station equipped with an RF antenna and a touch screen display. The Local control Unit is located on the assembly line near the pick and place machine (or machines) placing the moisture-sensitive devices. Each time a reel or tray of sensitive components is added or removed from the machine, the operator only needs to place the tag near the antenna. The system will automatically retrieve the relevant information from the tag and database. The operator then performs a simple load or unload transaction using the touch screen. The system automatically keeps track of all the components loaded on the assembly line along with their location (machine and feeder position) and Remaining Exposure Time.



Fig 4: Local Control Unit

In order to assign a Remaining Exposure Time to each PCB entering the assembly line in first pass, barcode readers are

installed at the entrance and exit of the assembly line as indicated below:

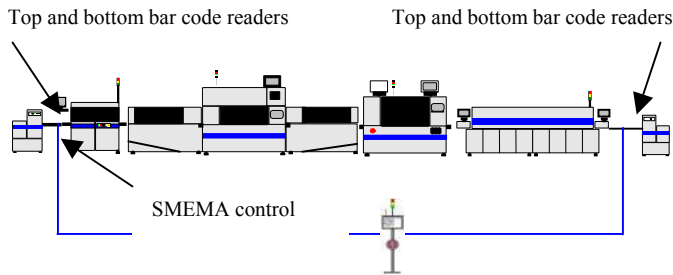


Fig 5 : Line Integration

The purpose for having two bar code readers at each end is simple. Since the bar code label is only on one side of the PCB, the system must be able to read the label when it is facing up in first pass and when it is facing down in second pass. Thus the first bar code reader is mounted on the entrance conveyor looking down from the top and the second reader, also mounted on the entrance conveyor, is looking up from the bottom. The second set of two bar code readers at the exit of the line is necessary to confirm that each board went through the process successfully. This is an additional control step in case of a line breakdown or if boards are manually removed from the line before the process is completed.

A SMEMA interface enables the system to stop the line if an error condition occurs.

The two bar code reader kits and SMEMA control box are all connected to the Local Control Unit. The Local Control Units (a minimum of 1 per line) are networked to a central server that provides the central database and consolidates the data from every line.

PROCESS CONTROL

The main objectives of the system are to make sure the product is built per the guidelines of J-STD-033, prevent assembling components that have exceeded their floor life and prevent assembling boards in second pass that have expired components on them. This guarantees the product is free of reliability problems related to moisture-induced defects. The challenge is to perform all this while maintaining an efficient operation on the manufacturing floor. Keeping this in mind, it becomes useful not only to validate the boards are built with components that are not expired during first and second pass, but also to make sure the boards are built with components that have enough floor life to go through the process until the second reflow is completed. In order to achieve this, the system uses two parameters configurable by the user:

- FPMRET or First Pass Minimum Required Exposure Time (in hours)
- LPMRET or Last Pass Minimum Required Exposure Time (in hours)

The FPMRET and LPMRET define the minimum exposure time required by the system to let the production run during first and second pass without interruption. A “Product Editor” enables the engineer to define the list of moisture-sensitive devices for the product along with other characteristics like the pass number and FPMRET or LPMRET values.

To start production, the operator must first select through the user interface, the product part number to be run on the assembly line. Once the product is chosen, the system performs several validation tasks, which can be summarized as follows:

A PCB enters the assembly line:

After the barcode reader reads the PCB serial number, it is stopped on the conveyor before it enters the first machine and will remain there until all the validation steps are accomplished successfully. The system will first verify if it has any first or second pass data for it. If not, it assumes it is a new serial number. The system then verifies that all the moisture-sensitive component part numbers required to run this product in first pass are loaded on their respective pick and place machines. If not, the system will provide a list to the operator of all the component part numbers required to run the product. The system will also provide a list of all the component part numbers not required but currently loaded on the pick and place machines and alert the operator to remove these part numbers and place them in safe storage (dry cabinet or dry bag). At that point, the operator needs to load the missing reels or trays of components and remove the unused reels and trays by scanning their respective tags and performing a load or unload transaction. When this is done, the system will verify the status of the Remaining Exposure Time of all the sensitive components loaded on the assembly line and select the one with the least Remaining Exposure Time. The system compares the value to the FPMRET parameter and will assign the RET to the board if the criterion is met and will release it for production. The system will perform the proper error management and alert the operator if the FPMRET criterion is not met.

During all the time the board undergoes first pass process, the system will assign a “in process first pass” status to that board. When the serial number is read by the barcode reader at the exit of the assembly line, the status of the board is changed to “completed first pass” and some basic information about processing of the board are logged into a historical database (line name, date and time, RET at exit, override condition)

A first pass board enters the assembly line for second pass:

The process control in second pass is very similar to the first pass process. On top of all the validations described above, the system will also verify that the board successfully completed first pass before letting it go into second pass processing. The system will also verify the board and

components loaded on the pick and place machines have enough floor life remaining to meet the LPMRET criterion and apply the proper error management if not.

During second pass processing, the system will assign a “in process second pass” status to the board and will update it to “completed second pass” when the serial number is read by the exit barcode reader. Again, some basic information about processing of the board are logged into a historical database (line name, date and time, RET at exit, override condition).

USER INTERFACE

In multi-shift operations, several operators are involved in the manufacturing process of a given batch of boards. Adding to this the complexity of tracking moisture-sensitive devices during the first and second pass, considering on top all the other tasks the operator has to perform, it became obvious the user interface for the system had to be easy to use and intuitive. For this project to be a success, it was important to get the acceptance from the operators. This is usually possible only when the operators see a benefit in using a new system by making their lives simpler and easier instead of seeing it as “just one other thing to do”.

Because of the RFID technology, the operator has very little to do to perform a transaction since the data acquisition is triggered automatically by presenting the tag to the antenna field. Most transactions are performed without any keyboard data entry and the software is designed with built-in validation that maintains data integrity throughout the process.

Process buttons on the left side of the main user panel give access to process panels, each taking care of a specific aspect of J-STD-033.



Fig 6 : Process panel example

Whenever information has to be provided to the operator about what to do next or whenever an error occurs requiring an operator intervention, the appropriate message is displayed in the “System Messages” area. From the main panel, there is a “Watch Lists” button that provides access to the real time inventory, physical location and Remaining Exposure Time status of the materials on the assembly line.

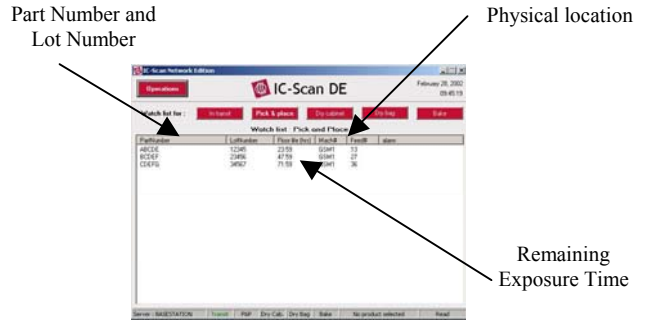


Fig 7 : Watch list

Since warnings and alarms can be set in the system, the Watch list will display visual alarms and text messages whenever a warning or alarm condition is met and trigger the light tower whenever appropriate.

The user interface includes a search tool that provides visibility and status of all the materials on all the lines including boards.

CONCLUSION

The control of moisture-sensitive components is a complex issue that has several implications in many critical aspects of the material flow and assembly processes. For double sided boards with sensitive components on the first side or both, it becomes very difficult to ensure the product is built per the guidelines of J-STD-033 without the implementation of an automatic control system.

The installation of the Cogiscan system at Delphi Delco Electronics Systems provided an efficient method to control moisture-sensitive devices during the assembly process while providing relevant information for decision-making. The operators adopted the system quickly since all the complexity of J-STD-033 was taken out of their hands. There was a significant reduction of training especially for new operators since they do not need to be MSD experts anymore but simply follow the instructions provided by the system.

Delphi Delco Electronics System maintains a high commitment towards quality and the initial driver for this project was to prevent moisture-induced component failures. By automating the component-tracking activity, machine operators are freed to focus on other quality and productivity-related tasks and MSD control becomes independent of operator skills and training levels. The implementation of the system can lead to a very straight forward financial justification because of savings due to improved quality, productivity and material costs.

REFERENCES

1. J-STD-033, IPC/JEDEC, April 1999
2. Jean Lamontagne, Jean-François Rouleau, François Monette, Should You Automate Control of Moisture-Sensitive Devices?, Circuits Assembly, May 2002
3. Phil Zarrow, MSD: What you don't know may be killing you, Circuits Assembly, June 2002
4. Handling of Highly-Moisture Sensitive Components – An Analysis of Low-Humidity Containment and Baking Schedules, IEEE ECTC, 1999, R.L. Shook and J.P. Goodelle, Lucent Technologies