Survey of RFID case studies

Few technologies have recently received as much attention as RFID (Radio Frequency IDentification). There are as many different types of RFID technologies as there are different types of barcode readers, labels and data formats. In the maze of technical and marketing information it becomes difficult to understand the real capabilities of different products and to set realistic expectations for any RFID project.

The electronics manufacturing industry represents an excellent environment for RFID applications. After all, the factories that make the tags and readers should be the first ones to benefit from this technology. What is unique about our industry is the very large number of different components and materials that must be located at the right place at the right time. Most of these items are very expensive and many have special tracking and control requirements.

This paper provides an overview of successful RFID case studies in our industry.

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RFID for supply chain vs. factory floor

The perfect universal RFID tag and reader does not exist. As a matter of fact, the ideal technology depends on the specific requirements of each application, including the physical constraints associated with different types of items to be tracked, the physical environment and other factors.

Although most of the attention has been focused on using RFID to improve material tracking in the supply chain, in the short term the most significant benefits can be realized by using RFID to increase the level of automation on the production floor. The first reason is simply that it will take a lot of time for the industry to agree on a specific RFID technology to identify raw materials and finished products. This is evident by the fact that even today there is still no such standard for barcode labels on plastic reels, the most common container of electronic components. In addition, the cost of RFID compared to traditional barcode labels must be justified throughout the supply chain. At every step in the process, the users must evaluate the cost and complexity of installing the proper readers and integrating this in their existing material tracking systems. Somehow the actual cost of attaching an RFID tag to each item must be justified and absorbed by the suppliers, distributors or the end customers. To the author's knowledge, only a few case studies have demonstrated the technical feasibility of this type of approach in our industry. One of the most notable being the Philips Semiconductor application in Asia as reported in the report titled "RFID: Impact on Electronic Products and Manufacturing" by Technology Forecasters[1]. The financial viability of supply chain applications of course depends greatly on the individual price of the RFID tags. Although many analysts and suppliers are predicting the prices of RFID tags to come down to $0.05 in the future, the most cost-effective RFID tags, called smart labels, are not currently available at prices lower than $0.30 USD per unit, even in very large volumes. On the other hand, the technology is quite effective when RFID tags are used in a closed-loop environment within the factory floor. In this case the tags can be attached permanently to a wide variety of carriers and tooling that are re-used continuously. Another alternative is to use a temporary attachment method to track consumable items throughout the assembly process and re-use the same tags over and over again. With this approach the cost of the tags can be amortized over several batches of materials and over time they become more cost-effective than single-use barcode labels. What is also unique about the electronics factory floor is the large quantity of small items that must be located in tight spaces, often in close proximity with metal surfaces, which are generally not compatible with radio frequency communication. For example the typical bill of materials required to build a PCBA (Printed Circuit Board Assembly) includes in excess of 100 different reels of components that must be located on metal tape feeders at specific locations on placement machines. Solving these challenges require a high level of expertise in RFID technology and a strong knowledge of the specific materials and equipment used in the industry.

RFID for moisture-sensitive devices (MSD) control

This is one of the most critical material tracking applications in the PCB assembly industry. Large electronics components that are encapsulated with plastic compounds are sensitive to the moisture in the ambient atmosphere and as a result they have a limited floor life. Exceeding this floor life prior to reflow can result in internal micro-cracks and delaminations that will jeopardize the reliability of the finished product. The allowable floor life varies from one type of component to another, from a few hours to a full year of maximum exposure at ambient factory conditions. MSDs are shipped in sealed dry bags with desiccant and humidity indicators cards. As soon as the bag is opened, the floor life clock starts, and it must be tracked until all the components in that bag have gone through final reflow.

In 2001 Cogiscan was the first company to offer a commercial system using RFID tags to automate MSD control inside a factory. The first year that this product was introduced at APEX, the industry leading trade show, its unique value was recognized with two Vision awards.

In this application, re-usable RFID tags are attached

Figure 1. Re-usable RFID tag on JEDEC tray.

Figure 2. Re-usable RFID tag on Reel.

temporarily to the standard plastic reels and matrix trays used to handle electronic components on the factory floor. The RF tags are scanned each time that the trays and reels are moved from one environment to another, such that the system can keep track in real-time of the physical location of each MSD, and automatically calculate the remaining floor life based on the complete history of exposure to different environments, including ambient factory, dry storage and bake ovens. Warnings and alarms are generated such that the production operators can insure that all product is built within the industry standard guidelines. Several leading electronics manufacturers have adopted this technology and many studies have been done to quantify the real-life benefits and ROI provided by this system. Here is a short list of these case studies. Detailed references are listed at the end of this paper, and a link to the complete documents can be found on the Cogiscan website under "MSD Knowledge Base / List of publications":

- 1. BAE Systems, Nashua, NH - MSD Control in a high reliability environment[3]
- 2. Celestica, Kidsgrove, England - Improved Control of Moisture-Sensitive Devices[4]
- 3. Delphi, Kokomo, IN - Controlling MSD for Double-sided Reflow Applications[5]
- 4. Solectron, Sherbrooke - Should You Automate Control of Moisture-Sensitive Devices?[6]

RFID for product tracking & error-proofing

This is another RFID application that takes advantage of re-usable containers and re-usable tags. The C-MAC factory in Sherbrooke, Canada, is manufacturing hybrid circuits using thick film technology on ceramic substrates.

In this process the ceramic substrates are handled in magazines from one operation to another, using automatic loaders/unloaders to move the substrates in and out of the screen printers. Since a typical circuit requires multiple layers of different types of metallurgy, a standard production sequence involves multiple repetitions of print and reflow, on both sides of each substrate. This means that the same substrates and magazines will go in and out of the same screen printer and reflow ovens multiple times. Each specific step of production requires that the right type of paste, the right squeegee, and the right stencil be used on the screen printer.

Each batch of product can include multiple magazines. The required assembly sequence is defined by a route that is specific to each different product. Considering the large number of variables it is easy to understand that this assembly process includes a large number of opportunities for human errors.

Figure 3. Re-usable RFID tag on jar of paste.

The objectives of the RFID automation project were to improve overall material flow and eliminate the risk of human errors. The first element of the system includes a series of RFID tags that are permanently attached to each magazine used to handle the ceramic substrates. Then a series of RFID antennas and readers are mounted on the loaders/unloaders for each screen printer. The tags are mounted off-center and there are two antennas at each magazine location such that the system can also detect if the magazines are loaded upside down; thus eliminating another risk of human error. The stencils are also identified with permanent RFID tags and the jars of paste are identified with re-usable RFID tags. Additional antennas and readers are mounted inside the screen printer to automatically detect these materials when they are loaded for production. The material tracking software application monitors real-time information from all antennas and ensures that each machine has the correct set-up for the specific product and sequence of operation, according to the magazine currently located in the magazine loader.

After each printing process the magazines are placed on a continuous conveyor that brings them to the reflow oven area. In this room there are multiple ovens running different temperature profiles that correspond to the different types of paste that have been printed. The main conveyor is equipped with a series of diverters that can switch the magazines to a secondary conveyor in front of each oven. The control system includes an RFID antenna and reader mounted directly below the main conveyor. Once a magazine reaches that point, the control system will verify the identity of the magazine and the specific product/process step that it contains, and automatically branch the magazine to the proper reflow oven. In this project C-MAC worked closely with Cogiscan and a third-party supplier of conveyor equipment to integrate the different systems together.

RFID smart feeders

Tape feeders for an SMT placement machine represent an excellent application for RFID. A typical PCB assembly plant requires a significant investment in capital equipment including placement machines with a very large number of different feeders for different types of components. In some cases the value of the feeders even exceeds the value of the placement machine itself. Knowing precisely the status and location of all tape feeders can lead to a more efficient operation by making sure that the required feeders are available when needed. The use of RFID tags on feeders also enables automatic validation of the feeders and reels on the placement machine. Fast and reliable feeder set-up validation is a critical success factor to minimize changeover time and eliminate human errors during machine set-up. RFID smart feeders in combination with a basic material tracking system also enable real-time inventory tracking, providing a fully automated means to track the remaining quantity of components in every single reel, on and off the placement machine. The most advanced feeder set-up validation systems offered by machine vendors involve the use of so-called 'smart' feeders. These feeders include some form of intelligence in the form of a programmable memory or a unique ID that is tied to the feeder and component information stored in a central database. The communication happens through an electrical contact when the feeder is loaded on the placement machine. This type of system can be quite expensive and it is dedicated to a specific brand and model of machine. This means that different machines will feature different levels of validation and a different user interface. Most importantly these systems do not offer real-time inventory of the feeders when they are not loaded on the placement machine. RFID offers a very low-cost alternative that can provide a level of control equivalent to or better than any other type of dedicated smart feeder. In addition to lower cost, the main benefit of this approach is that it can be retrofitted on any type of placement machine. In this application, RFID tags are attached to each feeder and feeder bank while readers are integrated in the machine feeder interface (*Figure 4* RFID Smart Feeder). The system must be designed in such a way as to precisely detect which feeder is loaded in each feeder position. If the readers are integrated in mobile feeder banks, this can also enable offline inventory and set-up validation. Since there is no electrical contact involved, there is no maintenance or reliability issue associated with pogo pins or others.

In addition to keeping track of the location of all trays and reels on the production floor, it is also possible to integrate the tracking system with the placement machines in such a way as to automatically update the remaining quantity in each reel when it is unloaded from the placement machine. This can increase the accuracy of real-time inventory and eliminate the need to manually count the quantity prior to returning partial reels in storage.

In the past, a few vendors of placement machines have offered feeder set-up solutions using RFID technology. The first generation of such systems was designed specifically for a turret-style chip shooter with moving feeder carriage. In this application, each feeder was equipped with a passive low frequency RFID tag and one fixed reader was mounted on the machine at the pick position. In a typical configuration one feeder carriage can be running production while the other carriage is in a park position, enabling the operator to load feeders for the next run.

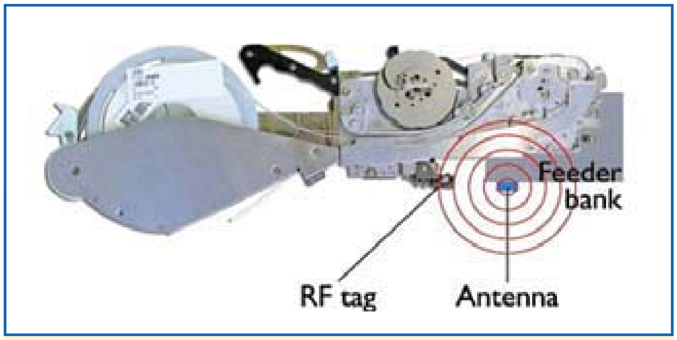

Figure 4. RFID tag on Juki tape feeder.

In this case, the component information is transferred from the supplier label on the reel to the feeder tag while the reel is loaded on the feeder on a special offline feeder set-up station that is equipped with a barcode reader and RFID reader.

Although this system is much more robust than traditional barcode-based systems, there are still two major shortcomings with this concept. The first issue is that the system is not completely error-proof. Since the single RFID reader is not continuously monitoring all feeders on the machine, it is possible that during reel replenishment an operator will remove a feeder, change the reel, and reload the same feeder in the same location without scanning the new reel. The second issue is related to the impact on the overall cycle time of the placement machine. Every time that the machine starts production, and every time that a feeder carriage is parked for feeder change, the machine must go through a complete scanning cycle. This requires the carriage to move slowly by the single RFID reader, allowing enough time to read and validate all the feeders. It is also important to note the fact that this single antenna concept is not very practical for placement machines with fixed feeder banks like most gantry pick and place machines. In this case the single RFID reader has to move across the feeder bank via some form of semi-automatic or motorized shuttle. The physical space required for this additional hardware limits the options in terms of retrofit kits for existing machines. The additional hardware and the associated moving parts also have an impact on the overall machine reliability and maintenance costs because of the mechanical wear factor over time. In comparison, the most advanced RFID smart feeder systems use a special design of reader/antenna to continuously detect the location of each feeder at each feeder location. As a result the feeder set-up validation task can be accomplished in real-time as the operator is loading and unloading feeders from the machine. The main benefit of this approach is to completely eliminate the risk of human errors without impacting the overall cycle time of the placement machine. Another advantage of this approach is that the RFID reader/antenna can have a very low profile such that it becomes possible to retrofit any kind of placement machine that was not originally designed with this option in mind. And, last but not least, the same approach is equally applicable to machines with fixed or moving feeders, making it the first truly universal smart feeder solution. As a matter of fact, this approach is so flexible that similar RFID reader/antenna can be mounted in offline mobile feeder banks and feeder storage carts to provide the same level of real-time inventory and control for all components and feeders on and off the placement machine. Juki Automation AG was the first major vendor of placement equipment to incorporate this leading edge technology in their new machine offering. In this case the RFID smart feeder hardware was introduced in the IFS-X intelligent feeder option, replacing the prior smart feeder system that used electrical contacts. The main benefit of this technology upgrade for Juki and for their customers was to increase the overall reliability of the system and further reduce the cost of ownership for their machines. The leading provider of tape feeders, Hover-Davis, also recently announced that all of its Siplace-compatible tape feeders will include an RFID tag as a standard feature. In this case the major benefit for Hover-Davis and their customers is to simplify the retrofit process to convert existing 'dumb' placement machines into 'smart' machines and feeders.

RFID for traceability

There is a growing requirement by electronic OEMs to gather data and provide material traceability in the manufacturing process. This can range from recording component lot code information for a few critical devices on each batch of boards, all the way to complete material and process traceability for all components, chemicals and tooling, on each serialized board and assembly.

While demanding traceability from their EMS providers, OEMs are placing an increased emphasis on data integrity.

They understand that it is pointless to request traceability if there are no checks and balances to ensure 100% data capture and accuracy. This is motivating assemblers to error-proof their traceability systems. Manual scanning operations and open-loop systems are being replaced by fully automated closed-loop material detection systems. Safeguards are being incorporated to automatically prevent production unless the specified traceability data has been successfully recorded.

In our industry, the upcoming lead-free and RoHS legislations will also dictate a much higher level of material traceability, as the assemblers will be responsible to demonstrate that all materials used in the production of a specific product meet regulations. RFID can enable these applications and make them more practical, more robust and cost-effective by reducing the transactional overhead associated with barcode scanning all required elements and eliminating the risk of human errors.

Conclusion

There are many significant obstacles that prevent assemblers from properly controlling materials on the production floor. In the past the industry has been using a collection of disparate material tracking and data acquisition systems that rely on a combination of manual data entry and barcode scanning, without the benefit of standardized information or labeling formats. The mainstream adoption of RFID technology introduces the opportunity to leapfrog to the next level of automation, using RFID technology to seamlessly identify, track, and validate that the right materials are at the right place, at the right time and under the right conditions, without any human intervention. When this new technology is introduced in a way to maximize its potential benefits, it has the potential to connect and integrate various types of machines and systems via a common and standard architecture for material data acquisition. All of this can be achieved with RFID technology that is available today. The costs of RFID tags and readers can be easily justified based on the savings associated with improved material and process control including higher quality and reliability, as well as reduced material and manufacturing costs.

NOTE : Cogiscan has several pending patents relative to the applications described in this paper. For more information on this subject contact Vincent Dubois (vdubois@cogiscan.com).

Figure 5. RFID tag on Hover-Davis tape feeder.

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