Making Ovens Smarter

Time to turn-up the heat to focus on oven intelligence

This white paper sets out the anomaly that is the lack of intelligence available in ovens compared to elsewhere on the production line and the clear benefits of making the oven smarter. If you were handing prizes out for intelligence on the shop floor, I suspect the oven wouldn't get the first prize, yet we have devoted so much time to factory intelligence and the path towards what many are calling the Smart Factory.

IoT and big data are colliding to create the opportunity to automate the SMT line, and indeed the rest of the manufacturing processes, in a way that hasn't been possible before. Terms like Industry 4.0 and IoM (Internet of Manufacturing) are being used to support and to promote the development towards a factory where every machine can play an intelligent role, interacting with the data provided from and to other pieces of equipment.

This white paper seeks to set out the value of a 'smarter' approach to the reflow process and how a more intelligent oven can offer real added value and performance to the entire line. It also lays out some of the criteria that is important when selecting smart equipment for a smart process, that conforms to, and is ready for, IoM or Industry 4.0.

Some things genuinely don't need to be intelligent. They are simply able to do the task they are required to do without interaction. This isn't the case with the reflow oven, which plays a pivotal role in SMT (Surface Mount Technology) assembly. Without this process operating within the correct tolerance level, the entirety of the processes, will have happened for nothing. The oven is where the bill of materials and their carrier, the PCB (Printed Circuit Board), become one single robust connected unit.

The industry is now using the term 'IoM ready' or 'Industry 4.0 ready' to define a process or equipment that adds value in an industry 4.0 or IoM environment. For simplicity, this paper defines IoM or Industry 4.0 ready as the ability to read, record and relay. That is to 'read' the material that enters the machine, to 'record' the parameters of the process that occurs, and to 'relay' that data externally and openly.

What's to be gained from smarter ovens?

Quality control is essential for this, as it is for every other process and whilst there are various inspection and test processes that occur afterwards, they are largely 'go' or 'no-go' tests and do not account for the hidden risks around soldering outside the process window of the board, the components and the solder paste. Whilst testing and inspecting will pick up many, or even all, failures in the assembly process, they will not detect problems that may cause a product to fail later in the field. The challenge of robustness is a growing one as component design makes inspection harder and the mission critical nature of many PCBs means that solder joint quality needs to be assured well after the product leaves the factory gates.

This quality can only be assured if the oven is operating within the specification and tolerances of the various elements contributing to the process, such as bare board material, solder paste and components. Thus, if the oven cannot 'read' the materials coming in, 'record' every parameter processes as they occur, and finally 'relay' that data, then the quality of the output is subject to some guess work and some level of variability and risk.

Product manufactured at the edge of specification or process window may well look perfect and work well in the controlled environment where they are tested, but may be producing latent risks that eventually lead to field failures or recalls. Studies have repeatedly shown that reworked PCBs are more prone to field failures compared to PCBs that were assembled perfectly the first time. These kinds of quality issues are a ticking time bomb for a brand's products. They are very expensive to correct and can be extremely damaging to reputation.

Good quality control in production can very easily be translated into dollars on the bottom line. Reduced scrap and lower rework costs all contribute directly to profit and the ability to deliver on-time in an extremely competitive world.

For smarter factories to really add-value they should not just produce more reliable products, they should do so more economically, more efficiently, and using less energy. The drive to constantly improve operational excellence is unrelenting, but the rewards are substantial. Smarter ovens should be able to play a role in producing greater yields, lower waste and simply be more resourceful. We will cover line efficiency further on in this paper, but clearly smart ovens are capable of ensuring that every board is soldered within the process requirements, achieving the optimum solder joints and hence the best possible yield, while optimized for low energy consumption.

When we talk about efficiency there are a number of elements at play. One is the amount of product that can be processed by an oven within a given time, another is the amount of labor required to process that product. Intelligent systems, such as those employed in an IoM or Industry 4.0 environment require the line to display greater intelligence and hence require less manual input, allowing labor to be deployed at higher value work elsewhere in the factory. There is also no doubt that the oven has a great deal to contribute to the harmonization of the line and the overall efficiency of the line. Elements like downtime, changeover time, or the pulse or tact of the line, all impact on performance and making decisions that take into account the thermal management of the oven's zone, can impact on line utilization.

Changeover time can be particularly impactful, costing an increasingly large percentage of production time. As the industry moves into a world of higher mix, higher complexity and lower volumes, changeovers become more and more significant and the time spent on the process more valuable.

With intelligence comes understanding, and with understanding comes the ability to learn. A lot has been made about artificial intelligence in an automated or smart factory environment and thus the so-called 'cyber physical systems' of Industry 4.0 that require that process can be improved using learned experience. This experience is the data that comes from a smart process.

These intelligent systems have the opportunity to learn and to learn fast. This greater velocity of fault detection or potential fault detection as a process nears the edge of its window or tolerance, means that errors are detected faster, producing less waste and accelerating the corrective action. Ideally potential problems are detected before they occur and corrective action means no defect product is produced. Thus, the intelligent oven saves more money.

The days of consumers choosing any color as long as it is black are rapidly being replaced by mass customization. This means shorter production runs and more frequent production line changeover. While the focus for line optimization tends to be the pick & place machines, productivity requires a more holistic approach.

Because the reflow ovens can take up to 45 minutes to stabilize on a new recipe, they can frequently be the bottleneck in line changeover downtime. Smarter ovens can dramatically reduce changeover time in a variety of ways.

For instance:

- Identify a common recipe that can accommodate numerous unique PCB assemblies
- Identify a new recipe that maintains the current zone temperatures and only changing the conveyor speed
- Smart database analysis to suggest new oven recipe without the need to initially profile for fast NPI setup
- Intelligent production scheduling

Processes that cannot, or are not measured, cannot be improved

Smart ovens should be capable of providing data that not only improves their own performance, but also the performance of other elements within the oven, such as pastes and laminates. Data from the oven, like the data from every piece of equipment has two clear benefits to offer. The first is the immediate and local impact whilst the second, potentially even greater, benefit is where the data from multiple lines or multiple sites is mined and used to develop better equipment, better processes and better consumables.

Crowd sourced data has a great deal to offer the industry and the ability to pool data, confidentially and anonymously, has potential to benefit everyone in the entire value chain. Better machines, better consumables, better processes and as a result better performance are all available from mass generated data. Imagine systems, processes, consumables and equipment whose design and development is informed by millions of results produced worldwide. A large multi-site organization with hundreds of lines would also have analysis of various environmental, machine and consumables combinations, making for better machine investment selection. The industry can already see the beginnings of this with new reflow ovens that provide setup recommendations without running a profile by the use of an intelligent database data mined from other similar ovens.

Traceable and transparent

Compliance, use of conflict or banned materials, root cause analysis and the desire to have the complete genealogy of a product has driven companies to require very high standards of traceability. Some of these requirements come with industry specific certification like in the automotive and medical sectors, whilst customers needing to maintain tight control throughout their entire supply chain impose others.

One key benefit of an intelligent manufacturing process or machine that complies with the IoM and Industry 4.0 demand to read, record and relay data is that complete traceability is delivered without any additional work being required. Traceability and transparency can really be by-products of a system that has operational excellence as its goal.

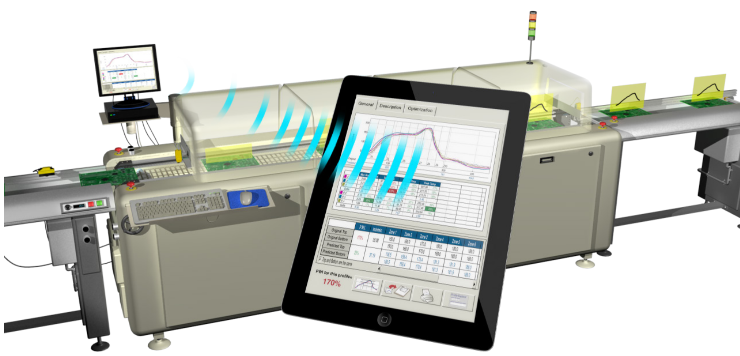
Raw data isn't enough and the ability to take headline performance numbers and display them in a simple legible way combined with the ability to mine down to the detail behind them is now expected. Data needs to be fully transparent to look through the trends and headlines and to the raw data input to create detail for analysis and for corrective action.

Running blind, or even partially sighted is not acceptable

It seems that for some time reflow has been the only part of the line where running blind or perhaps partially sighted has been considered acceptable. This is perhaps because the trend to sub-optimize the oven or to set the oven up for as broader performance window as possible has been prevalent. This won't work with some of the current technologies, which have much tighter tolerances. Micro BGAs (Ball Grid Arrays), PoPs (Package-on Package), 01005 geometry devices all create tighter and tighter tolerance demands, leading to smaller process windows and the need to tune the line and in particular the oven to each board. Having the right data to choose the right recipe is now even more important.

Relying on spot-checking the process is for a growing list of companies no longer adequate. A continuous real-time measuring of the processes' adherence to established specification is required due to the steadily smaller margin of error and the numerous opportunities for unexpected process changes. One common example specific to the thermal process is temporary changes to the factory's exhaust system. Moving from spot-checks to continuous automatic profile verification prevent a single PCB from being processed out of specification, while providing thermal process visibility to the whole factory via MES or similar networked solutions.

There is no doubt that the electronics industry continues, and will continue, to become more demanding, both technically and economically. This is made even more challenging by the need for lines to handle a higher mix of products with multiple changeovers on every shift. Flexibility and agility have to exist hand in hand with exceptional quality and reliability in a fully traceable environment.



So, what data do we want from our smarter ovens?

We can only improve a process that we measure so, whilst machine data, such as zone temperature and belt speed is important, it is less valuable than process data, which provides the actual profile of the board as it passes through the oven.

By way of a checklist, the following machine data is a minimum requirement:

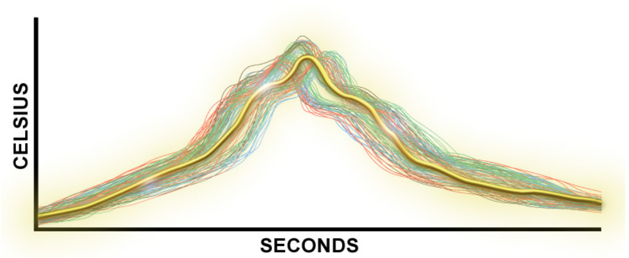
- Board in and board out count, time stamped
- Oven set points
- Actual zone temperature readings
- Oxygen levels
- Fan speeds
- Oven status (ready, adjusting, shutting down, starting up, maintenance)

Additional the following process data is needed:

- Board identification
- Oven recipe – is this correct for the board that is entering the oven
- Process window details
- Profile data for PCB relative to the relevant process window
- Consumables identification – chemicals, paste, etc...

Of course as with any form of education, there's a good way and a bad way to make things smarter, and sensors for sensors sake is not the right solution. Starting with an understanding of what is needed from the oven should lead to the 'right' kind of intelligence being applied.

The first consideration, as in every area of manufacturing, is the 'machine or process monitoring' debate. Understanding whether the data needed can be reliably extracted from the machine, or only by process monitoring is the first stage of creating intelligent systems that add value. Within the reflow oven there are numerous variables that can be measured: heat developed, conveyor speed, power consumption, vibration, nitrogen consumption and many more. Selecting the right measurements is essential in monitoring any performance and thus is the starting point in the selection of your monitoring process.



Improvements can only be made on what is measured. The reflow oven's primary job is to heat solder paste to a point where it reflows and produces good conductive joints throughout the PCB, while adhering to the tolerances for components, substrate and solder paste. This requires more definition from all the vested parties, but in essence good solder joints are what the oven is being asked to produce and this is currently measured using a 'process window'. This is the agreed process tolerance range within which the result achieved is acceptable for all the vested parties. Within the process window solder reflows, creating good reliable joints, components are not damaged or compromised, and the substrate remains intact.

To achieve the desired process window a temperature profile is needed. This is the time versus temperature data as the PCB passes through the oven, and this is governed simply by controlling conveyor speed and zone temperature or heat transfer. Therefore, the oven has a simply defined role to play. It must operate at production speed applying an acceptable profile to each PCB.

Machine monitoring measures the variables within the system that impact on an outcome, whereas process monitoring measures the outcome. Selecting the right solution is simply about selecting the data that is required. If the concern is that a machine specification will drift over time, machine monitoring will help measure and potentially prevent that. If the concern is around the quality or the solder joint and its reliability in the long term as well as delivering complete traceability and process improvement, then process monitoring, and process monitoring only, will do that.

Having established that processes are what are to be monitored, the next stage is to understand how best to monitor them. Until recently the common technology employed was to spot check the reflow process using a profiler. A profiler will pass through the reflow oven exactly as a PCB would, reading and recording all the required data as it goes and finally relaying that data to the outside world.

Software is then needed to compare recorded data with desired data, as well as confirming that the recipe or profile is correct for the PCB in process. This assumes that software is available and able to create the right recipe in the first place, ensuring that all the elements of the process are used in specification and tolerance. The software will need to create simulation to achieve the required results, preferably using data sourced and evolved over many operations.

The smart oven concept goes one step further and measures all of this data for each and every PCB. It would then be able to operate alarms and warn of certain situations such as the profile falling out of specification or getting too close to the edge of a process window. In certain extreme instances it may shut down the conveyor upstream to the oven to avoid any out of spec production.

The data will need to be shared in an open protocol that properly supports the PLM (Product Lifecycle Management) and MES (Manufacturing Execution System) software being used within a facility. Holistic data approaches, not just in manufacturing, but also throughout the supply chain, are the essence of any IoM and Industry 4.0 deployment strategy, and this is where the smart oven can really add value to the whole manufacturing ecosystem.

This is where the data from the oven and the predictive nature of the system can simulate different manufacturing scenarios and decide which will achieve the greatest efficiency for the entire process. For example, a smart factory system should be able to consider the changeover time of each piece of equipment or each process from any given PCBA (Printed Circuit Board Assembly) to another. Only by considering every scenario can it plan the best possible production schedule for a shift, learning as it goes and influencing future decisions. This is where real value can be achieved from the data extracted.

All of this needs to be done on multiple platforms, such as mobile devices or using augmented reality through 'Google Glass' or similar visualization devices. A good factory wide intelligent system would include a number of different configurable dashboards that allow the user to see only what they need to see, with the option of mining deeper into the data shown when that is required. Operators, managers and customers all have differing demands for data and by providing the same information to everyone, the real value to some may be missed. Each data user will ideally be able to customise reports and dashboards, but would have the back-up of the raw data to build detail as and when needed.

Smart ovens are essential for smart factories and smart supply chains. Building intelligence into every part of the process has a huge potential for an individual line, individual business and for the whole manufacturing industry. Conversely and successful deployment of an IoM or Industry 4.0 initiative, or even a simple transparent or traceable solution, will fail if a single piece of equipment does not share the same 'smart' philosophy as the rest of the line, factory or supply chain.

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Thank you for reading

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