Technical Article

Reflow Soldering of RoHS compliant power electronic assemblies

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LTi Electronics Ltd. is an independent EMS service provider, who is supporting the general market as well as the LTi group of companies. The expertise of the company rests in satisfying quickly, flexibly and reliably the stated requirements of their customers. LTi Electronics combines the complete manufacturing know how in the areas of board layout, logistics, assembly of boards and devices (box build), as well as the complete test functions in one source. The production capacity consists of 2 SMT lines, 2 wave soldering systems and a fully automatic selective coating process for electronic assemblies. LTi has a total of 120 employees.

For their customers, which mainly come from the areas of industrial automation, medical technology, air conditioning and ventilation technology, electrical drives and the regenerative power technology, LTi offers an all-embracing service for their complete manufacturing requirements in regards to electronic assemblies and all associated tasks.

Market Situation in the EMS Industry

The market situation for EMS service providers has, over the past years, markedly intensified. The challenges due to global competition have confronted companies with the need to continuously reduce the “time to market” for their products, frequently accompanied by very high expectations and demands by their customer base. At the same time, this global competition has exerted immense cost pressures on them. Therefore, and despite rising quality requirements, production costs and capital commitment should be permanently lowered.

The rapid development in the field of electronics, specifically in the area of components and printed circuit boards, brings with it the possibility to increase the functionality and the level of miniaturization, even in the field of power electronics, where this had not been suspected.

Additional challenges are being posed by the world-wide increase in the number of laws and regulations being passed pertaining to the protection of the environment. Conformity of their products to RoHS, even though they do not fall under the regulations, is more and more demanded by customers from the industrial electronics sector. These requirements force companies to switch their manufacturing processes over to the use of lead-free alloys. The specific characteristics of these solders increase the complexity of the processes, and requires much additional process knowledge and the most modern and capable soldering systems, so that a stable and reproducible process can be ensured despite the smaller process window.

Even though many of these requirements seem to contradict each other, modern manufacturing technology has found ways to actively participate in implementing them. At LTi Electronics GmbH these high demands are mirrored in their everyday production environment.

Fig. 1: E. Schmauch, Managing Director and Howard Little, Process Technologist LTi with the HOTFLOW 3/20

The Product Spectrum of LTi

Because of the relatedness and the roots of LTi in the drive technology, the product spectrum of our own group of companies is very varied. It encompasses everything from simple circuits and control boards up to power electronic assemblies.

Modern power electronic boards of the drive technology are based on multilayer technology with heavy copper layers. The component mix of these assemblies goes from fine-pitch SMD's up until heavy mass SMT components with a very high demand for heat energy during production.

The number of components per assembly may sometimes be very small, which results in very short pick-and-place cycles. These short cycle times have to be realizable as well from the subsequent systems of the production line, as otherwise the condition called "bottle neck" will restrict the total output of the complete line.

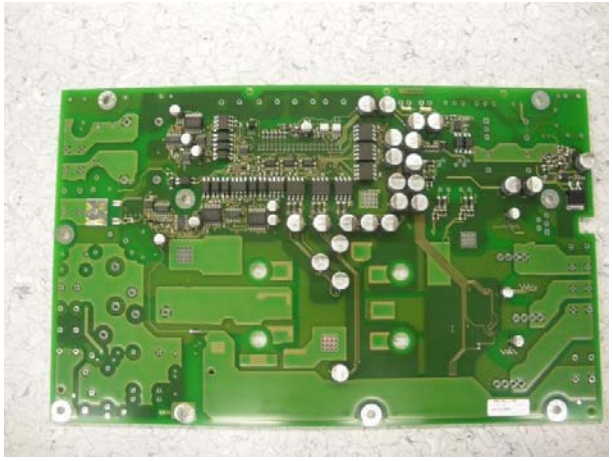

Fig. 2: Power board with high thermal requirements

The difficulty now existed in soldering these assemblies, requiring for once large amounts of heat while at the same time requiring adequate soak time to heat right through, in a reflow system at very short cycle times. For the new SMT line, on which these assemblies were to be produced, a reflow system was required which offered the necessary ability to gently but effectively heat the board within those tight and difficult to achieve specifications.

Evaluation of the Reflow System

Four well known suppliers of reflow systems were short-listed for evaluation of their products. The goal of the tests was to establish which system was most capable to gently heat the board as required. For this proof, it was necessary to select a number of critical points on the assembly, and to record the temperatures found at these locations. Thermocouples were attached to locations where large masses requiring heat were found, as well as to those where very small SMT components / joints were located. In addition, the ability of some critical components to tolerate the elevated temperatures was established. These key points – heat requirement on the one side, ability to tolerate high temperatures on the other – define, after allowing for the tolerances, the process window in which the assemblies need to be manufactured. Violating this process window, will either lead to thermal damages or incompletely formed solder joints, because the solder paste deposited could not, because of insufficient amounts of heat, properly reflow. Both of these defects could possibly remain undetected in the immediately following ICT or functional test, yet they could later in the field cause a catastrophic failure. Since field failures represent the “worst case”, and since they can be very costly both on a financial basis and in the damage afflicted to the corporate image, they need to be prevented at all cost. For this reason, soldering is a key process, with a degree of importance on the total life expectation of the assembly that should never be underestimated.

To proof that the limits of the process window were maintained, the temperature difference (Δt) measured between the different solder joints should be as small as possible. The minimum temperature of the coldest joint measured should be more than 235°C for 20 seconds. The ability of the components to tolerate the heat was recorded separately, and analyzed according to the datasheets of the suppliers.

The measured results of our tests after having visited and tested three of the four potential suppliers were rather sobering. One supplier was unable to process and solder the board within the required process window. Two other suppliers had to go to the limit of their equipment in order to marginally maintain the process window. For a user, this is a rather unsatisfactory situation. If the presently produced assemblies already take the system to the limit of its capability, what will be the situation in the future? Experience shows, that the demands on the process and the equipment will increase, not fall. In the worst case, that could mean that the system which had been selected today, could not fulfil the requirement for new assemblies tomorrow.

Decision for the HOTFLOW 3/20 from ERSA

After these experiences, we were very surprised by the results achieved on the HOTFLOW 3/20 from ERSA. It was the only system able to solder our product safely within the process window and at only 60% of system capacity. In the second pass already the soldering results were perfect, as they are specified in IPC A 610 D as the desired condition for class 3 Electronics.

The temperature Δ for our complex board was < 10 K. Another large advantage was the small difference between the zone temperatures and the temperatures as measured on the assembly. As proof of the ability to withstand the temperature experienced, the measured temperatures of the components and housings were all below the specified threshold values of the components as specified in the datasheets.

Since this positive result was achieved at 60% of system capability, there is assurance for the user that future boards with possibly higher demands can be safely processed. With the comforting knowledge of the existing reserves, the future seems much less taunting.

The precision, with which the reflow system was adjusted, was not achieved by chance. The simulation software “Autoprofiler” from ERSA was being used. This software is based on many years of experience in the reflow process, and a very good and clear understanding of the functioning of the system. It allows – after entering board type, component types and some additional key points relating to the required profile – that the temperature / time characteristics are simulated. Initially, the software will present suggested set points, which can subsequently be individually fine-tuned. The final set points of the simulation will be transferred into the system and stored as the solder program to use.

In this case – where finicky constraints were present – only minor modifications to the temperature set points were required to adjust to the "real" condition of the system. For our volume production this means, that a profile can be established off-line at the engineers desk, and that for the verification of the actual temperature / time course as experienced by the product, very little production time has to be sacrificed. The positive consequence of this is the increase in system availability for production.

In the meantime, the HOTFLOW 3/20 runs for the last year in a two resp. three shift environment, und all the positive results of the first hour have been confirmed over and over.

Advantages of the HOTFLOW 3/20

As is implied by the name, the HOTFLOW 3/20 reflow system is the third generation of a proven concept, and it builds up on the HOTFLOW 2/20, the first reflow system designed and build specifically for lead-free soldering.

To be "best in class" in all areas of process and design was the objective of the revision undertaken. The times, during which just any reflow oven could be integrated into a production line, are passed. Today, operating costs paired with the performance of a system play the central role in the purchase decision.

One further significant point contributing to the purchase decision is the excellent heat transfer rate of the system. The HOTFLOW 3/20 has 20 heated zone (10 from the top, 10 from the bottom) as well as 8 cooling zones (4 from the top and 4 from the bottom), which gives a total process length of more than 5 meters. This process length permits conveyor speeds of about 140 cm/min. This translates, with a board length of 200 mm, into a throughput over 3 shifts of about 7500 assemblies, with the optional dual track this could be increased to about 15 000 assemblies or with the quadruple track to 30 000 assemblies per day. To achieve this excellence in the heat transfer, ERSA relies on their proven Multijet technology. The transition of the heated medium – either air or nitrogen – from the heater cassettes into the process zone is effected by a large number of small jets. This jet technology applied is unparalleled on the market. Comparable systems on the market from other suppliers have only perforated plates, which can give rise to turbulences and cross currents.

With the application of the Multijet technology, the HOTFLOW 3/20 avoids these undesirable effects. The heated medium is not swirling around in the process zone, but is targeted directly on the board surface and the components. This predominantly vertical movement of the heated media and the homogeneous distribution of the 660 jets of each heated zone virtually assure the equal distribution of the thermal energy across the complete conveyor width. Additionally, the Multijet technology applied provides a very effective zone separation. The temperatures of the 20 heated zones of the system can be individually set, so that even small adjustments in the temperature/time equation can actually be realized. The heat transfer rate can be varied through

the speed settings of the blower motor. Preheat and peak zone, upper and lower, both can be individually and separately set and defined in the solder program.

Fig. 3: View into the process zone of the HOTFLOW 3/20

The cooling area of the HOTFLOW 3/20 features another new development with the integrated controlled cooling loop into the first cooling zone. The cooling gradient required for different assemblies can now be set in the solder program, and since the temperature in the cooling zone is actively controlled, the temperature in the cooling zone remains absolutely constant.

To maximize the operational availability, it is necessary to be able to easily and quickly perform all the maintenance required on the system. An important contribution to this is provided by the condensation management system. This feature very effectively removes contamination (condensate etc.) out of the process atmosphere and prevents soiling of the process zone. The condensation management system of the HOTFLOW 3/20 is of multi-stage design. Preheat and peak zone have separate systems, and the contamination of either is purposefully precipitated in the supplied filter units. These filter units are redundantly supplied, and one always can therefore be opened and maintained without having to stop production.

The deployed materials in the HOTFLOW 3/xx series are of very high quality, something which is also reflected in the purchase price of the unit. But only through the deployment of these high quality materials is the high uptime and operational availability safeguarded. In glaring contrast to this, low-cost equipment from other suppliers is sold exclusively via their low investment cost. Yet, the frequent down times of these system drastically lower their availability for production, causing the production volume to miss the required target, so for example when defective components have to be exchanged that require inordinate amounts of time, or when spare parts are not immediately available. These are added, cumulative costs over the life of the system.

Wear parts and spare parts of the HOTFLOW 3/20 are designed with the goal to be exchangeable within the shortest period of time possible, in order to maintain the high level of operational availability.

Ersa GmbH

Conclusion

The HOTFLOW 3/20 from ERSA offers to the user real added value. In the application described above, very complex and challenging power electronic assemblies are produced in a mix with standard boards. All products are soldered gently and effectively in large volume and short cycle times. The quality of the solder joints is excellent and fulfills all requirements and criteria of IPC A 610.

The cost-effectiveness of a soldering system today is not to be defined by an allegedly low initial investment, but first and foremost by its operating cost and its operational availability. For this reason, equipment with low energy consumption / low energy cost, a high level of flexibility in profiling and a high operational availability should constitutes the first choice for any electronic manufacturing plant. Only by adhering to these requirements can stability and reproducibility of a RoHS conforming process for the broad board spectrum experienced by an EMS service provider be assured. Achieving a high level of quality of the boards produced (first pass yield) and at the same time having low operating costs are the key ingredients when facing the global cost pressures found in the EMS industry.