Dispensing: A Robust Process Solution for Shield Edge Interconnect

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Abstract
A new process has been developed for RF shielding on compact electronic communications devices using automated solder paste dispensing. The process is known as Shield Edge Interconnect (SEI). SEI designs enable parts to be processed though underfill before placing of the RF shield and allows more complete use of valuable PCB real estate to achieve reduced form factor requirements and/or for added components on products such as smartphones and tablets. The reduced form factor creates challenges for the assembly of those devices. This process, enabled by Speedline dispensing technology, relies on extremely accurate dispensing of solder paste on copper traces located along the outer edge of the PCB. The result is a robust process solution for SEI in which proprietary closed loop dispenser, pump, vision, and software technologies enable a high volume manufacturing (HVM) process.

Introduction
Radio Frequency (RF) Shielding is one of the oldest processes used to protect electronic components on a Printed Circuit Board (PCB) assembly from RF emissions and electromagnetic interference (EMI). It is used in a wide range of electronic products including cell phones, tablets, PCs, and home appliances. Numerous regulations enacted by agencies including the FCC (Federal Communications Commission), NEPA (National Environmental Policy Act of 1969) and OSHA, limit the emission of RF signals from a device. In the past, such metal shielding took the form of soldered perforated metal cans and metallic fences, or plated gaskets with EMI covers. Advances in communications technology resulting in products with greater power and functionality has led to miniaturization and high density packaging in PCB assembly. This has further driven complex designs with reduced PCB real estate and footprints with variable SMT pad dimensions <500µm. The challenge of high density packaging over smaller PCB real estate has driven OEMs to look for PCB edges as a potential area for shield placement. One approach has been to *'think in 3D'* in terms of the attachment area by routing copper traces along the outer edge of the PCB, a process known as Shield Edge Interconnect (SEI). SEI optimizes PCB real estate and provides added space on the PCB for additional components that will provide added functionality at lower cost, with components being located 300 to 400 microns away from the edge pad. Speedline has developed an innovative new approach to SEI utilizing precision

automated solder paste dispensing for SMT RF shield attachment. The process requires high-precision dispensing capability enabled by specific hardware (dispenser and pump), machine vision and software configurations. A singular advantage of this approach is that it enables underfill routines to be performed before placing the shield cans onto the PCB, rather than through perforations in the shield, as design limitations in the past required.

This new SMT process has been demonstrated to facilitate new space-saving attachment designs while creating a robust soldered connection for SEI along the vertical surface of the outer edge of the PCB. Solder paste is dispensed onto the bare copper pads of the PCB along the traces or the perimeter where the shield will be placed. This paper will illustrate and describe the SMT SEI process steps using dispensing for SEI.

Current Shield Placement Techniques

Shield attachment to date has involved either of two methods. In the first method, a "metallic fence" is formed around the perimeter of the area to be shielded. Then a spring loaded "metallic lid" is snapped over the fence to enclose the area. The mechanical contact between the lid and the fence creates the shield. *In the second approach,* solder paste is applied to the bare copper pads of the PCB along the traces or the perimeter where the shield is needed to be placed. The shield is then placed and soldered using standard reflow process. This is a one-step process. This latter approach has gained considerable popularity because it cuts out a process step and requires less PCB real estate.

The Shield Edge Interconnect (SEI) Process

The key to a successful SEI process is to uniformly dispense a controlled amount of solder paste accurately at the edge location to provide the optimum shield interconnection. Properly implemented, the process will dispense paste on the edge copper traces such that 50% of the solder volume is on the top of the edge pad, and the remaining 50% solder volume is deposited on the side trace of the edge pad for good bonding between the shield and the substrate edge. As such, the typical dispensing is in close proximity to the edge of the PCB, which creates a unique challenge. This challenge is met using a highly-controlled traditional auger pump, considered the best choice for solder paste dispensing, followed by software technology in process development of edge detection (of the PCB) for high process accuracy as well as strict control of dispensed line width.

SMT Line for SEI Assembly

The inherent simplification of the one-step shield attachment process also creates a complete metallic (solder) bond surrounding the entire PCB that makes the RF shield highly reliable. Low temperature lead-free (no-clean) solder alloys are used to attach RF shields. This is because an SMT PCB assembly that includes RF shields must 'see' two reflow passes; the first to attach the SMT components, the second to attach the RF shields. Although the first pass will typically involve higher-temperature lead-free solder (e.g., SN100C® @ 227°C.) to form the solder joints for the component leads, one does not want those solder joints to see liquidus or even near-liquidus temperatures a second time due to the potential for oxidation degradation, de-wetting, and other problems. It is also desirable to limit the degree of thermal cycling of the board to minimize the potential for damage associated with thermal stress. Consequently, the second pass reflow for shield attach is achieved using low-temperature melting alloys, such as a Sn/Bi/Ag alloy with a melting temperature point below 140°C. **Figure 1** shows a typical flow scheme whereby the PCB is assembled with components and reflowed in the standard manner. Following those process steps, the low-temperature solder paste for shield attach is dispensed, the shield is put in place, and the assembly is reflowed.

As mentioned earlier, the nature of the SEI process in the SMT line is compatible with and provides advantages to other dispensing applications such as underfill where dispensing systems can implement the underfill process without the presence of RF shield cans on the PCB. This provides a significant advantage to the underfill process as restrictions on underfilling through the RF shield holes designed by the OEMs can be avoided.

Technology Considerations for SEI

Key process control parameters essential to achieve successful SEI include the following:

1. Precise control of solder volume dispensed per pad/interconnect area;
2. PCB edge sensing accuracy – absolutely critical for this atypical dispense application;
3. Ability to dispense varying solder paste types (including types 3 through 6);
4. Ability to dispense pastes via varying needle sizes (IDs);
5. Precise line (solder bead) width dispense accuracy; and
6. Repeatable consistency of deposition over high volume/throughput.

Pump Capability

Establishing pump capability is key in developing a robust process for SEI. The Camalot Model 635 Servo Drive (SD) pump, an auger based system, was chosen for this application because it has demonstrated the capability to deliver a reliable process in the solder paste dispensing arena. It is well suited for line type applications with viscous materials, and incorporates a patented positive shutoff/no drip design. Capability analysis (Cpk) of the pump is conducted on line widths measured by dispensing different solder volumes or bead widths. Data is statistically validated with variability plots of multiple line widths presented in **Figure 3.** Results presented in Figure 3 have shown 635 SD pump capability with tolerance of 10% over average or target given by the customer. This precision is critical to the SEI process, since high variability in the solder volumes can result in serious failure defects including 'shorts' and 'opens' since most of the lines are dispensed on the edge pads of the PCB where solder volume and solder bead width are critical. Such qualification was necessary in proving the suitability of this auger pump model for the SEI process.

Dispenser Platform

SEI, as mentioned earlier, requires high precision dispensing capability in terms of location, line width, speed, and other factors. The advanced capabilities of the pump, as well as vision and software enhancements are of little relevance if the dispensing platform is not equivalent in terms of performance specification to address the advanced challenge presented by SEI. For this reason, the dispense platform chosen for SEI process development was the Camalot Prodigy, a recently-introduced dispensing platform with the required performance specifications and capability of incorporating the pump and vision systems needed. The dispensing system has an accuracy of +/-35 microns at 3 sigma, and repeatability is +/- 10 microns at 3 sigma. This is supported by high acceleration speeds of 1.5g in motion to dispense packaging materials at independent locations. Accuracy and speed are supported by linear drive technology, refined motion control architecture, and a rigid, frame design plus a robust X Y gantry system. With more compact PCB real estate come more compact assembly line configurations as well; this has been the trend in facilities producing smartphones and other personal communications devices. Manufacturers configuring such lines favor more compact machine footprints and more flexible configurability to provide maximum throughput with minimal floor space. The Prodigy dispenser's footprint is 830mm wide with a two-zone configuration. Hinged panels allow opening and access even when installed in a tight in-line configuration.

Software Capability

Software capability is critical to effectively program dispense locations based on the design of the PCB and dispense requirements. 'Line dispense' commands with parameters aligned to the auger pump capabilities are used to design the dispensing process. With The SEI application challenge is to address the dispensing process for the edge pads, as the coverage area is very unique to traditional solder paste dispensing. This is where a newly-developed feature known as 'Edge Find', based on vision algorithm, drives to accurately locate the edge pads of the PCB and ensure that dispensing is accurate with optimum solder paste coverage.

Vision System and 'Edge Find' Requirement

A state-of-the art vision system was designed and developed to provide the advanced vision capabilities required by SEI. The camera system used is equipped with digital vision enhancement with sub-pixel definition. These hardware enhancements maximize the accuracy of the fiducial locations, components and pad edges, to provide additional features including visual inspection for automatic deposition monitoring.

The primary objective of 'Edge Find' or 'Edge Def(ine)' is to allow the vision system to find the edges of the PCB accurately. To execute this feature we use a 'Locate Edge' command where the user is required to teach the edge pads of interest. This 'Locate' command for edge find uses same options as used for our standard fiducial, but instead we teach the edge of the copper pad as the model the user will access the 'Locate' template for Edge Find in the program. A sample template showing how the template appears with respect to a PCB edge pad is shown in **Figure 4.** This figure also depicts the edge pad of the PCB with *and* without the RF shield on the other side, in case the SEI process requires shielding on both the sides of the PCB. The software and vision capabilities show the different options for the user to teach the pad accurately. The vision system and software has the ability to distinguish the edge pad from the shield if there is a shield present outside the edge pad and accurately dispense on the edge of the pad.

Once the edge pads are taught accurately using the 'Locate Edge' command option, the software and vision have capabilities designed to move to that position at the beginning of the SEI process and search for the second edge of the pad to trace a complete edge. **Figure 5** provides a snapshot of how the software will execute the search algorithm.

Figure 5 shows the edge of the PCB is traced by teaching the position of the edge pad on the PCB. If the edge pad is located on the left-hand edge of the PCB, the user selects 'Right Edge 2' to look for the second edge coming from the right to left side of the PCB. If the edge pad is located on the top edge of the PCB, the user selects 'Bottom Edge 2' to look for the second edge coming from the bottom to top side of the PCB. Similarly, different edge pads at different locations can be taught by the user, using the locate edge feature in the process program. It is highly recommended that the locate edge feature always be taught in pairs. The software has the capability of teaching multiple edge pads to have higher accuracy and account for manufacturing variability such as shape, size, and discoloration

Following the locate edge feature taught by the user at different edge pad locations, the user must use the command 'Edge Line' or 'Edge Dot'. The Edge Line or Edge Dot command is taught in similar fashion to the standard Dot or Line command. However, in this case, the Edge Line or Edge Dot will use the reference position as the edge of the pad or PCB such that 50% of solder volume is on top of the pad and 50% on the side of the pad. The process herein described is critical to the dispense quality along the edge pads for the SEI process.

Combined Effect – Software and Advanced Vision System

The combination of the advanced vision system for edge pad recognition with algorithms developed within the software enables a 9 or 13 microns (µm) per pixel resolution, necessary for the vision to detect edge pads and other pads as small as 50 microns in width or diameter. The combined technology takes into account the variability of the edge pad shapes where less than ideally-shaped edge pad could still be detected by our vision system accurately so as to dispense the right volume of solder paste. This constitutes a key difference between the screen printing and automated dispensing processes where dispensing can accommodate the natural variability inherent in the edge pad traces due to PCB fabrication tolerances.

Line Width Measurement and Line Width Adjustment

In addition to the edge-based feature described above, line width measurement and line width adjustment features are critical to the SEI process. For this purpose, a template is designed to input some dispense parameters for dispensing lines. The pump automatically dispenses the line on the pre-dispense area and the vision system inspects the line to compute the bead width. Line Width Adjustment is an advanced form of process control that has the ability to monitor the accuracy of the amount of material dispensed and make adjustments automatically if the line widths are found to be out of tolerance or specification limits. This feature presents highly reliable process monitoring system critical in large volume production environments.

Conclusion

Shield Edge Interconnect (SEI) application using automated solder paste dispensing is a robust process that is dependent on strict process control. Implementation is dependent upon specific capabilities in the dispenser, pump, vision system, and software tools relative to line width control and edge definition capabilities. It creates a sufficiently durable RF shield connection to be suitable for mobile personal communication device assembly delivering products of high quality.

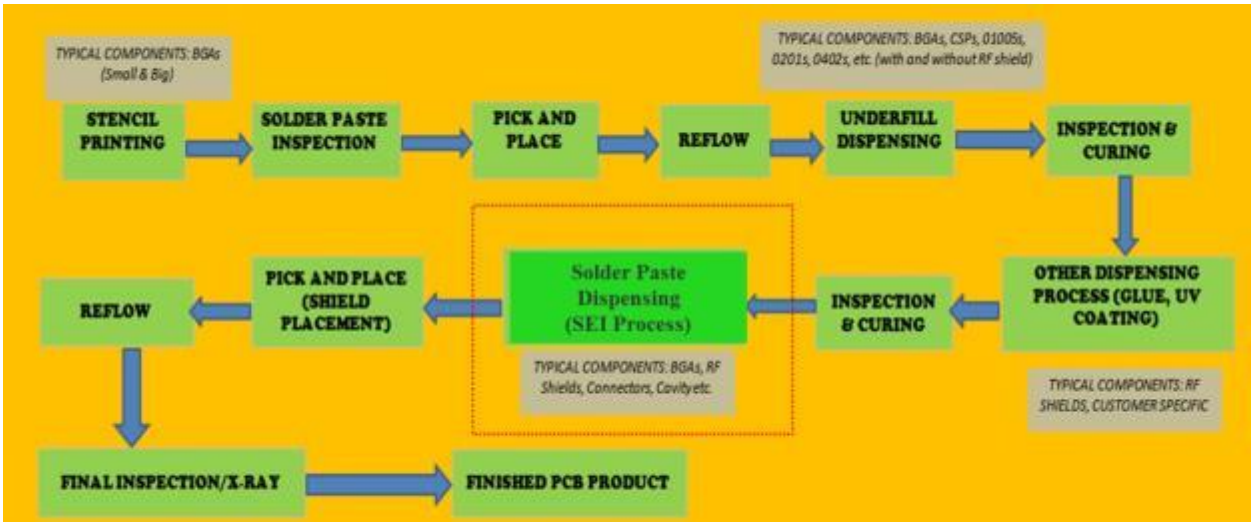

Figure 1. *Typical SMT line flow scheme incorporating the SEI process.*

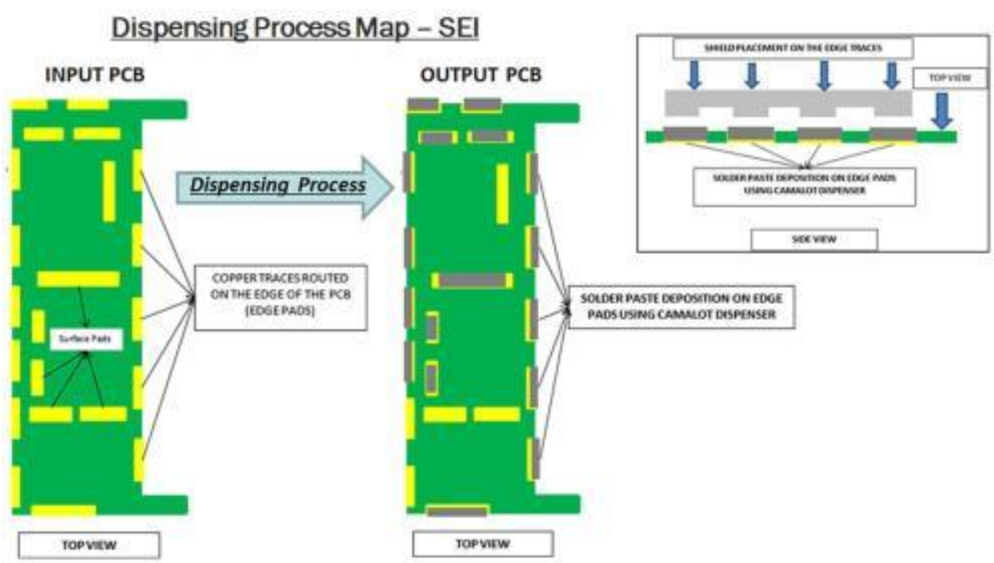

Figure 2. *Shield Edge Interconnects (SEI) Process with Solder Paste Deposited on PCB.*

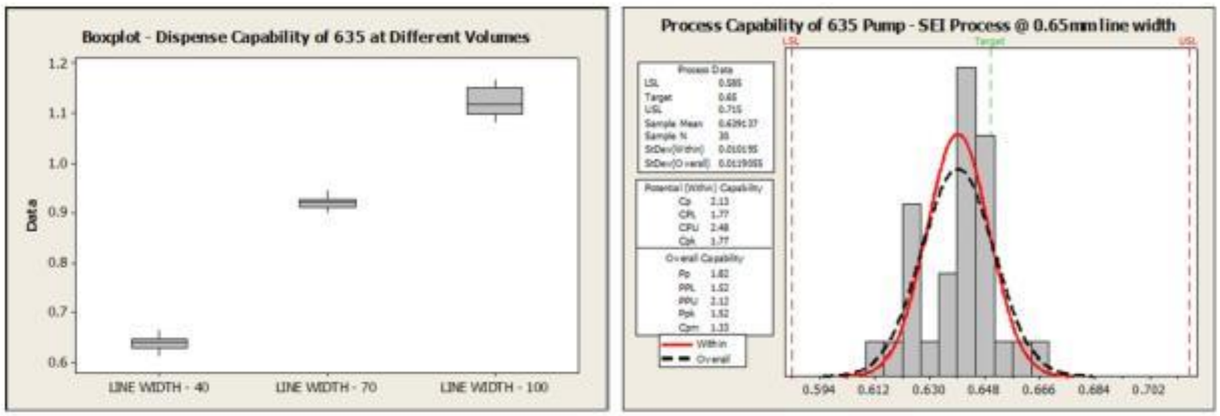

Figure 3. *635SD Auger Pump Performance Capability*

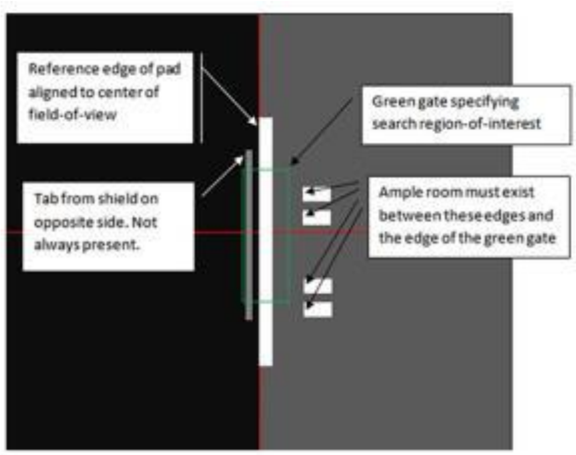

Figure 4. *Sample Edge Find Template in the Locate Edge Command for the user.*

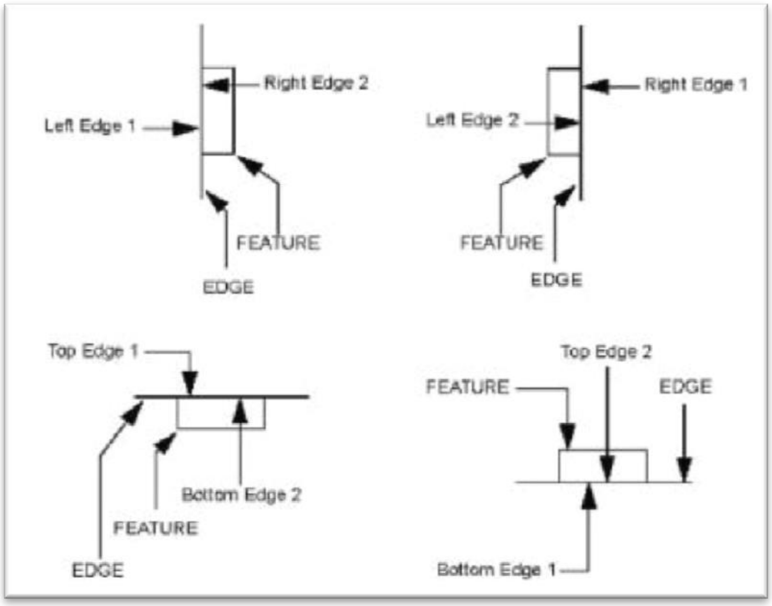

Figure 5. *Edge Find Tracking using software and vision System.*