Validating Press-Fit Connector Installation

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A winning combination: press-fit technology and installation by PC-controlled servo-electric presses.

The combination of press-fit pins and servo-electric presses provide a powerful technique for automating and verifying the integrity of board-to-board connector installations. Press-fit connectors have begun to dominate high-end connector applications for telecommunications and computer printed circuit boards (PCBs). PC-controlled servo-electric presses permit highly controlled press-fit connector installations. These presses also incorporate statistical process control (SPC) and documentation traceable to individual connectors for quality assurance.

Solid and Compliant Pins

The first press-fit contact was simply a pin with a rectangular, solid cross section. Driven into the round hole in the PCB, the four corners bit into the hole's plating, creating gas tight interfaces. The press-fit interconnection concept has similarities to the wire-wrap connections used extensively on boards in the past. These consisted of a round wire wrapped tightly around a square pin. The pin's corners bit into the wire, creating a highly reliable, well accepted, gas tight connection.

Modern press-fit pins incorporate a compliant mechanism that gives slightly as the pin enters the hole. Compliant press-fit pins come in several styles, including the C-section, action pin and eye of the needle (Figure 1). In all cases the section of the pin that is pressed into the board is several thousandths of an inch larger than the plated hole in the board.

The compliant mechanism in the pin compresses when the pressing tool forces the contact into a PCB hole. This compliance relaxes hole size tolerance, helps prevent damage to the PCB, provides spring force for retention and permits connector repairs. Depending on the pin geometry, insertion force can range from 2 to 45 pounds, while retention is usually about half the insertion force.

Pin insertion into the plated hole creates a gas tight joint. The high local pressure develops a cold weld effect, which provides both mechanical and electrical integrity. Although tin-lead plating is by far the most common hole finish, other finishes, including gold and bare copper, also result in successful installations.

Advantages Over Soldering

The press-fit compliant solution provides many advantages when compared with soldering, including:

- simple, clean, robust and highly reliable interconnections, even in high vibration and thermal cycling environments
- highly repeatable connection impedance, especially desirable in high frequency and high signal speed applications

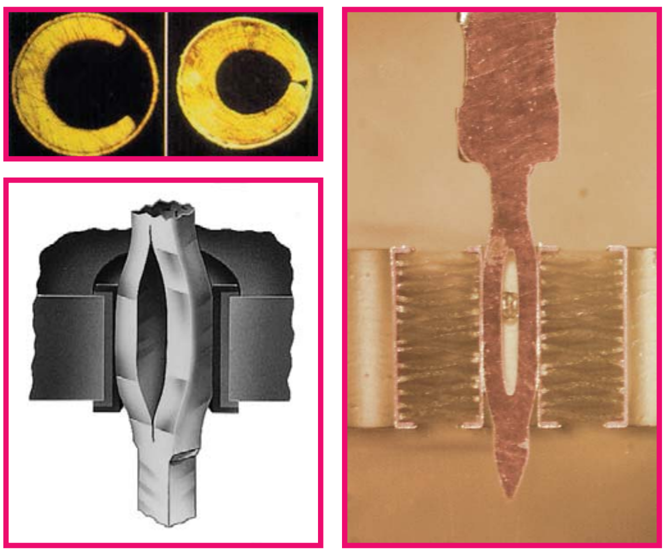

FIGURE 1: Compliant press-fit pins: C-section (top left), action pin (bottom left) and eye of the needle (right).

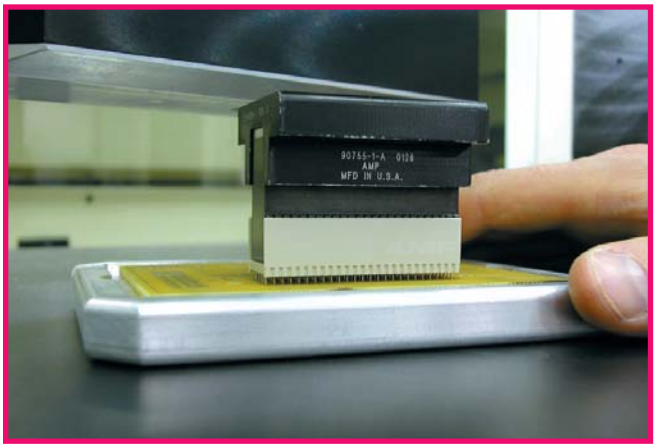

FIGURE 2: PC-controlled servo-electric presses precisely control the speed, position and pressing forces for installing press-fit connectors into PCBs.

- applicable to one or both sides of a PCB
- applicable to PCBs of virtually any thickness, except those of 0.060 in. or less
- easily repaired or replaced contacts or connectors
- surface-mount compatible and environmentally friendly process that requires no heat and no cleaning
- avoidance of special features for PCB ground plane layers to minimize their heat sink effects when soldering
- avoidance of high reflow heat, minimizing thermal stress on PCBs and damage to the plastic connector body from high temperature lead-free solders
- availability of mass terminating techniques, boosting production efficiencies
- amenable to high Cpk tooling and presses for documenting process quality control.

In surface-mount applications press-fit connectors eliminate the expense of wave solder pallets and masking. In many cases the combination of surface-mount and press-fit connectors can obviate the wave solder process entirely.

Connector Tooling

Connector manufacturers design and provide pressing tools specifically for each of their connectors. These tools are often referred to as *top tools* to distinguish them from the tooling that supports the PCB from below. Most press-fit pins have shoulders that the tool presses on, but some designs call for pins to be pressed on their tips.

Many connectors may be pressed by flat-rock techniques, meaning the tool can be a simple flat surface. Most right-angle daughter card connectors, for example, are amenable to flat-rock pressing, making specialized tooling unnecessary. For flat-rock pressing, the connector's insulating housing must be sufficiently strong to support the pressing force.

Bottom tools or fixtures support the PCB during pressing. These specialized fixtures can usually be used only for a specific PCB design. The connector pins often protrude through the PCB when pressed, so clearance holes or slots must be provided at all connector sites. Tooling pins in the fixture must pre-align the PCB holes with the fixture. Most manual and semiautomatic presses use a custom fixture to support the PCB under the connector being pressed. Fully automatic presses often use generic bottom support tools rather than custom fixtures. In this case the bottom tool automatically moves to each connector location.

Servo Electric Presses

Presses fall into such categories as manual, force assisted manual, semiautomatic and fully automatic. They can be flat rock or accommodate tooling mounted on the pressing ram. The pressing power can be supplied by a person or by pneumatic, hydraulic or servo electric systems.

Manual-, hydraulic- and pneumatic-powered presses lack fine control of forces and distances. They often require visual inspection of each connector installation to promote quality.

PC-controlled servo-electric presses (Figure 2) were developed for highly controlled installation of press-fit connectors. In these presses an electric servomotor drives a ball screw to provide the pressing force. Servo systems are designed for precision control of speed and position and can react nearly instantaneously to sudden changes in force. These presses can be either semiautomatic or fully automatic. Being controlled by a personal computer, they offer a superior operator interface, program and data storage, and networking capability.

Documenting Connector Insertion

Servo-electric presses sense and record the key press-fit connector variables, providing documentation of the press-fit process for each connector and board. Load cells measure the insertion force. With a servo electric press, force and position can be correlated for proper seating of the connector, eliminating the need for 100% visual inspection.

Figure 3 graphs insertion force versus distance as the pin of a 2-mm hard metric connector drives through the plated hole in the board. The vertical axis indicates the force in pounds per pin, while the horizontal axis represents the distance between the bottom of the connector and the surface of the PCB. The vertical line at 0.000 is the theoretical point where the connector body contacts the PCB.

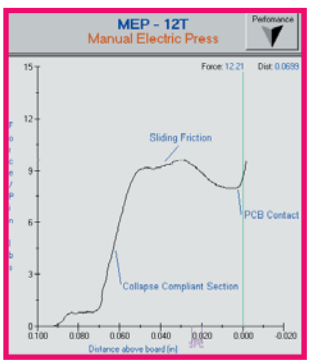

FIGURE 3: Force vs. connector distance to PCB for a typical compliant pin, showing the three distinct phases.

The curve exhibits three characteristic phases. In the first phase, the force increases in a linear manner, attributable to the resistance of the collapsing compliant section of the pin. In the second phase, the force is relatively stable, and the curve becomes somewhat horizontal. At this point the pin's compliant section has totally collapsed, and the force is simply that of overcoming friction as the pin slides through the hole. In the third phase, the force begins to sharply increase again because the connector body has contacted the board surface. The pressing cycle must terminate soon after entering the third phase to avoid damage to the connector and PCB.

Connector manufacturers specify a minimum acceptable insertion force that results in an acceptable connection and retention force. The most common cause of low insertion force is oversized holes from the drilling and plating operation. Verifying that the insertion force for each connector meets the minimum standards set by the manufacturer should avoid failures in the field.

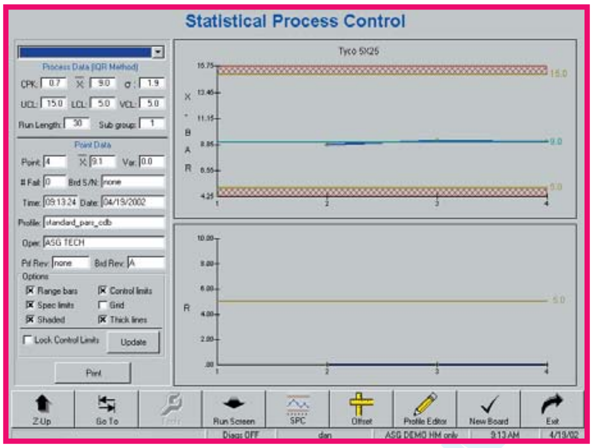

FIGURE 4: Average force (top graph) and range of force (bottom graph) for all connectors of the same type on each PCB.

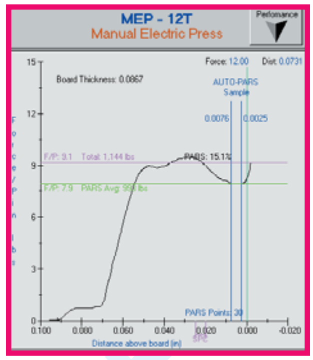

FIGURE 5: Stop press when force equals 15% greater than the average stable force.

Different connector designs produce different force curves, but the general shape of Figure 3 is representative. Additionally, different compliant section designs, as well as the PCB material and plating, contribute to variations in force curves.

Quality Control

Applying SPC to the press-fit process in the classic sense is nearly impossible, since the feedback loop to correct a process drift cannot be applied in real time. Also, the insertion force measured is necessarily an average force across multiple pins. Despite these limitations, gathering a representative average insertion force for each connector pressed, and generating SPC charts, can be a highly useful quality control tool.

The SPC force must be evaluated at a particular point in the process. The most representative part of the insertion curve is the second phase where the force is relatively stable. Manufacturers should always use the same SPC sample point to generate valid comparisons.

To benefit from SPC, you should understand the process variables that affect the measured process. The vertical axis of the upper graph in Figure 4 is x-bar, or the average force for all connectors of the same type on each PCB. This example shows the average force for each of the last four PCBs processed. The lower chart shows the range of force for the same connector type.

Cpk, calculated in the traditional way, provides a statistical measure of accuracy and repeatability—the higher the Cpk, the better. If a manufacturer consistently provides PCBs that result in insertion forces that are far from the center of the specification limits, the Cpk will suffer. In Figure 4 the process is consistent but below the center of the specification range.

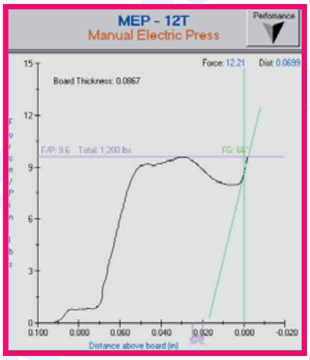

FIGURE 6: Stop press when the angle of force gradient is 66° or more.

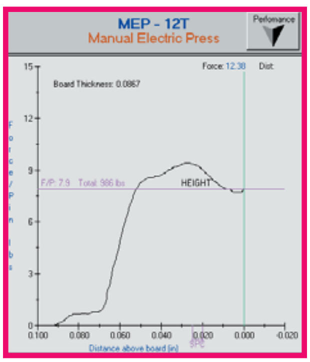

FIGURE 7: Stop press when the press reaches the known distance to the board surface.

The Cpk is often fairly high because the specification limits are usually very broad. However, PCB fabricators often bias the holes to the larger diameter tolerance and plate to the final hole size. The resulting insertion force tends toward the lower end of the specification. The top and bottom x-bar lines in Figure 4 represent the acceptable range of force. The bottom R graph gives the range of force (maximum minus minimum) for all connectors on the PCB. In this case the range is zero because only one connector is on the PCB.

Reviewing the SPC graphs during the first article inspection process provides a check so that the latest batch of PCBs produce insertion forces in an acceptable range. A new batch of PCBs will often cause a distinct shift in the SPC graph, particularly if a different manufacturer provides them. Insertion force monitoring and SPC charting is by far the best way to assess the ongoing quality of the press-fit process. Assemblers can optimize the press-fit process window by feeding this information back to the PCB fabricator.

Stop the Presses

On computer-controlled presses, intelligent algorithms can promote proper seating of the connector, while avoiding excessive force. Ideally, only enough force should be applied to a connector to seat it to the PCB surface. In Figure 5, the average force applied during the second phase, as the connector is pressed from 0.0076 in. to 0.0025 in. above the PCB, is 7.9 pounds per pin. The press cycle is programmed to terminate when the connector makes contact with the PCB and the force rises 15% above this average. Thus, the cycle terminated at 9.1

pounds per pin. This same connector on a PCB with smaller holes may require 12 pounds per pin in phase two and will terminate at 15% above 12 or 13.8 pounds per pin.

Another adaptive algorithm measures the angle of the force curve at the transition from phase two to three. This rate of change of force with respect to distance is sometime referred to as the *force gradient*. When the force gradient angle exceeds a preset threshold, typically ranging between 60 and 75°, the cycle terminates. Figure 6 shows a force gradient termination of 66°. In this case the press is programmed to look for the force gradient threshold only during the third phase of the pressing cycle.

Sometimes the manufacturer wants to press a connector to a specific point relative to the PCB surface but make little or no contact. A servo-electric press is ideal for seating a connector to a programmed position relative to the PCB surface.

In Figure 7, the pressing endpoint is the theoretical contact surface of the PCB. The force curve does not turn up because the third phase does not happen. This ultimate pressing technique only applies to the connector the force that is required to insert the pins into the PCB.

Computer Controlled Presses

To minimize operator intervention, a computer-controlled press can use databases of information on the tooling and connector to provide automatic setup for precisely controlling each pressing cycle. By protecting the pressing recipe with a password, the process engineer can be sure the press installs connectors in the same way, regardless of who runs the machine.

SPC charts provide visual feedback on the process. Most PCBs come labeled with a bar code serial number that can serve for identification. A computer-controlled press permits efficient and accurate hard-disk storage of each connector installation for tracing purposes.

In short, combining press-fit technology with installation by PC-controlled servo-electric presses permits PCB manufacturers to automate and validate board-to-board connector installations. Press-fit pins are a proven, time-tested technology that results in consistent impedance values. Adding the servo-electric presses for the final assembly of connectors into PCBs provides a highly controlled and automated finishing step with documentation that follows sound quality control practices. ■

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