A NEW METHOD OF CONNECTING WIRES TO SMT BOARDS

Janos Legrady
Zierick Manufacturing Corporation
Mount Kisco, New York, USA
jlegrady@zierick.com

ABSTRACT

This paper describes a new method of connecting wires to surface mount printed circuit boards. This new wire termination system is more cost effective than any other known method to date. It occupies little real estate on the PCB and withstands the most demanding environment.
The following subjects are discussed in this paper:

- Short review of pros and cons of PCB wire termination methods
- Description of the new method
- Testing

Keywords: surface mount wire termination, SMT wire termination, surface mount insulation piercing terminal, SMT insulation piercing terminal, SMT wire connection

INTRODUCTION

There are many ways to connect wire to a printed circuit board. Reviewing the benefits and limitations of the existing methods provides a better understanding of the new approach described in this paper.

CONVENTIONAL WIRE TERMINATION METHODS

Pin and Socket or Tab and Receptacle:

As shown in Figure 1, this method of wire termination is a two piece separable system. It consists of pins/tabs or receptacles mounted on the printed circuit board, with the mating half of the connector terminated to the wire, usually by crimping. This is the most commonly used method. It is reliable if done correctly despite its three connections. One is the soldered interface between the PCB and the pin/tab or receptacle, the second is the interface of the separable connection between the pin and receptacle, and the third is the interface between the wire strand(s) and the pin.

The main advantage of this system is that it is a separable connection capable of withstanding a large number of mating cycles. The disadvantage of this kind of wire termination is its cost. It is the most expensive of all methods because it requires two connector components, a pin/tab and a receptacle, two separate mountings, one to the PCB and one to the wire, and a final connection to mate the two halves.

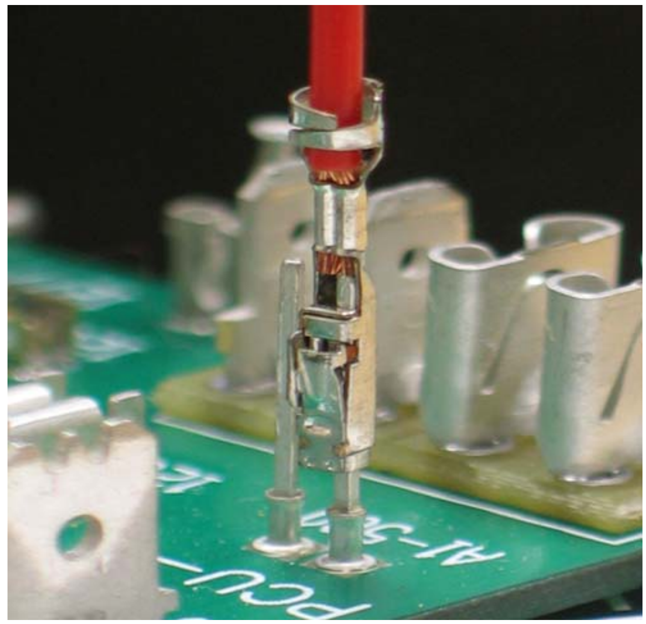

Figure 1. Receptacle connected to Pin on PCB

Solder Wire Directly to the Printed Circuit Board:

As shown in Figure 2, this system has a small footprint on the PCB and a single soldered connection interface. Its disadvantage is that it is usually hand soldered and therefore expensive. Additionally, the quality of the solder joint is operator dependent.

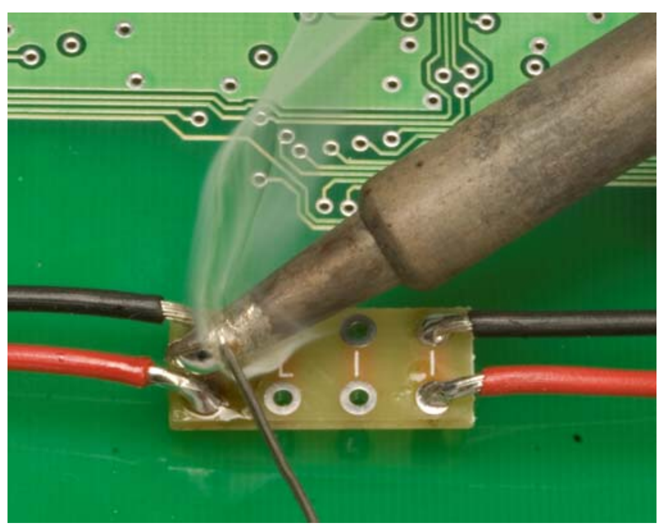

Figure 2. Wire soldered directly to PCB

While soldering a wire to a through hole board is relatively straight-forward since the wire is captive in the hole, it is more difficult with a surface mount board. The wire must be kept still until solidification of the solder to maintain the integrity of the solder joint.

Insulation Displacement Connector (IDC's)

Figure 3 shows a wire terminated to an SMT board using an IDC connection.

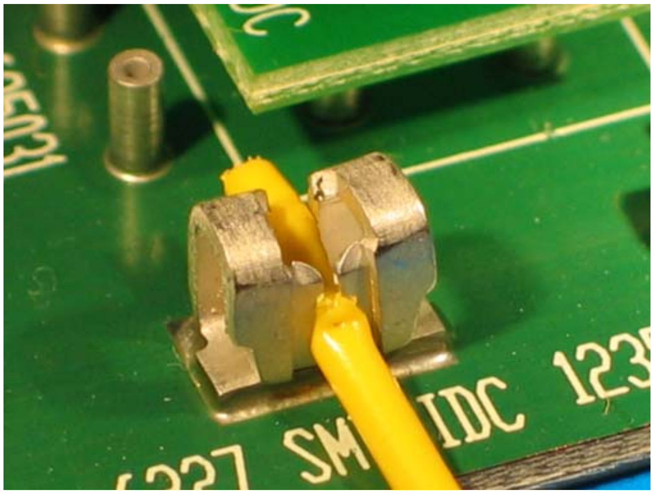

Figure 3. Torsion Insulation Displacement Connector (IDC)

The advantage the IDC offers is an economical way to terminate wires. It is a one piece connection system as opposed to the two piece pin/receptacle method.

Other advantages and disadvantages depend on the IDC type.

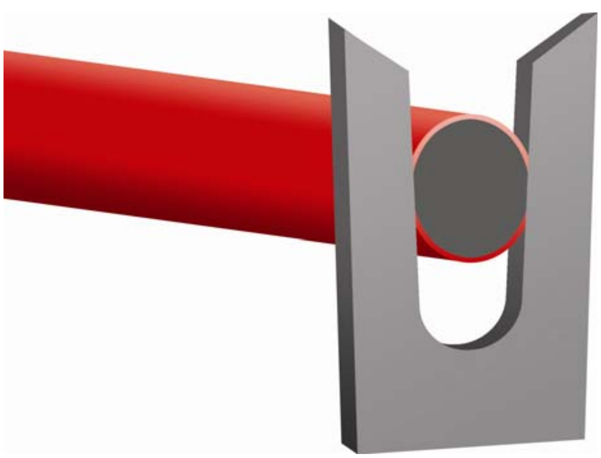

Figure 4. Conventional IDC

The conventional IDC shown in Figure 4, works well with one specific wire gauge in a "connection friendly" environment, but fails to withstand harsh conditions typical in industrial and automotive applications. It also needs a separate plastic housing to provide strain relief for the wire, thus losing some of the cost advantage associated with a one piece connection.

The Torsion IDC [1] shown in Figure 3 is an improvement over the conventional IDC. One single terminal reliably terminates a large range of wire gauges. It withstands the most demanding environments like shock, vibration and elevated temperature associated with automotive applications. The terminal can be mated and unmated several times unlike the conventional IDC. It may also provide partial strain relief.

The disadvantage of the Torsion IDC [1] is its large footprint, resulting from its classic torsion beam design, and the fact that it offers only partial strain relief.

SMT INSULATION PIERCING CRIMP TERMINAL

As everybody in the electronic packaging business knows, there is extreme pressure to produce a smaller, less expensive, and more reliable electronic assembly. Connection is still considered one of the weak links in the chain. The SMT Insulation Piercing Crimp Terminal was developed in response to the above challenge.

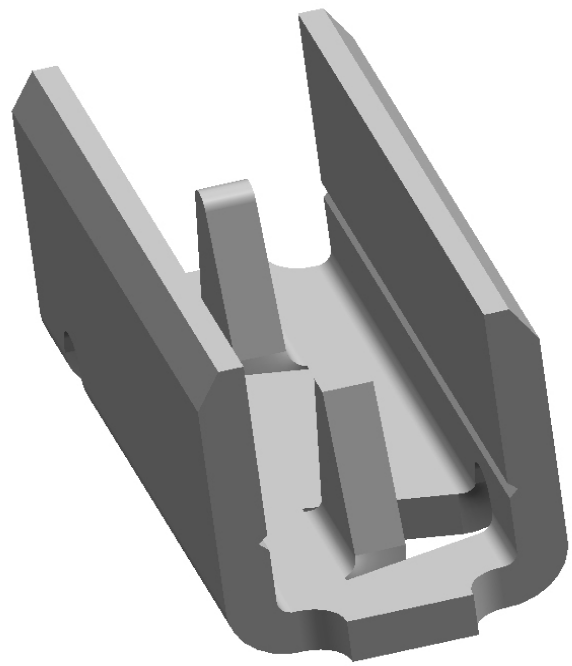

Figure 5. SMT Insulation Piercing Crimp Terminal

Figure 5 is a solid model of the terminal before being mounted on the PCB. The SMT connector consists of a flat base suitable for surface mounting. Two insulation piercing contact spikes protrude from the flat base. The terminal has two side walls perpendicular to the base. On each side wall there is a deep score line near the base, parallel with the terminal base. Inside the terminal, between the two contact spikes, there is a flat area to facilitate vacuum pick-up of the terminal by surface mount placement systems.

Figure 6 shows the connector being picked up by the nozzle, and Figure 7 shows the terminal being placed on the SMT board by the surface mount placement system.

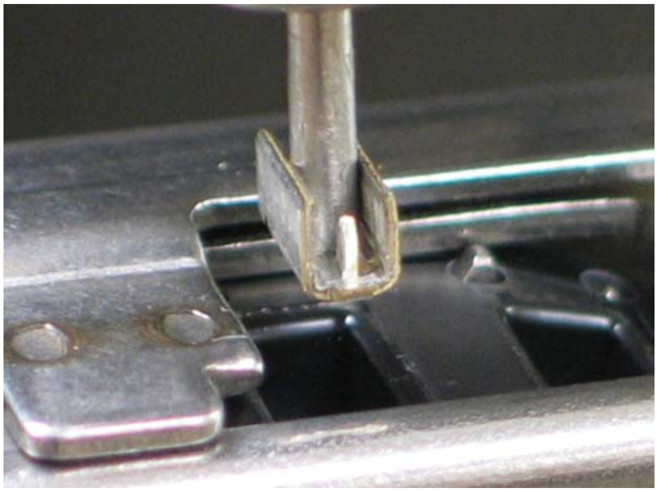

Figure 6. Vacuum pick-up nozzle picking part from tape

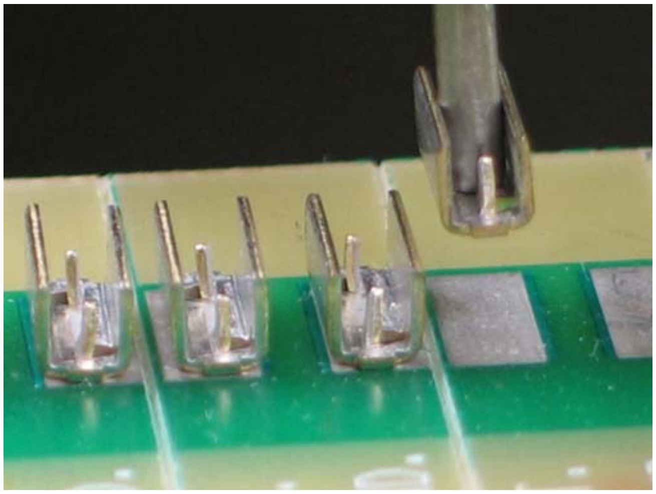

Figure 7. Vacuum pick-up nozzle placing part on SMT PCB

After placement of the terminal and all other components on the board, the assembly is sent through a reflow oven, where all components are soldered to the board.

Figure 8 shows the terminal mounted to the PCB after reflow. Notice that there are solder fillets all around the terminal base as well as inside the terminal in the two triangle shaped holes. These multiple soldered surfaces ensure strong terminal retention to the PCB. Two triangular apertures are created when the two contact spikes are lanced out of the base material.

These apertures provide not only extra solder fillet, but also a route for gases to escape. It is a known fact that when solder paste is reflowed, there is out-gasing. Trapped gases are detrimental to the integrity of an SMT solder joint as they create voids. These trapped gases are especially present when large flat surfaces like the terminal bases are soldered. The triangle shaped "vent holes" facilitate the exhausting of the gas, minimizing the formation of voids. The result is a

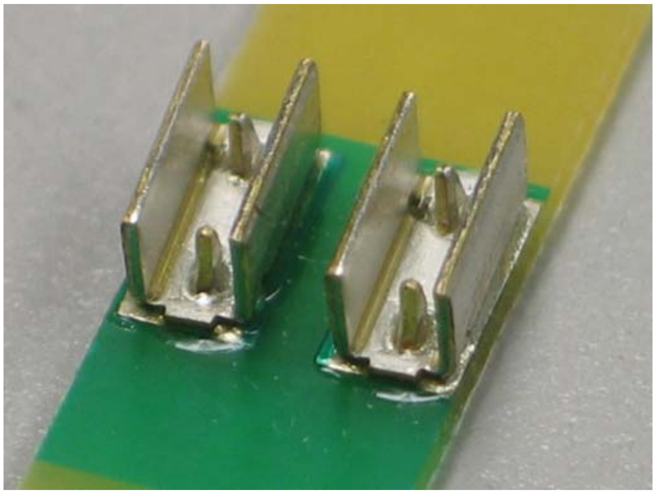

Figure 8. Crimp Terminal Soldered onto PCB

stronger joint which is more resistant to thermal shock and thermal cycling.

Figure 9 shows the mounted terminal with a wire placed in it just before termination. This step is shown for illustration purposes only.

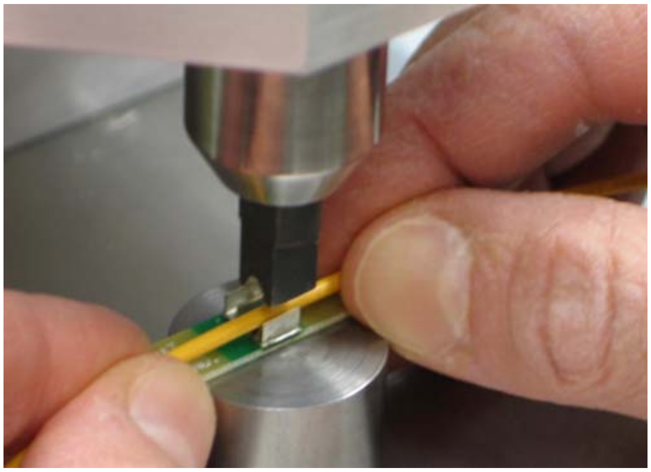

Figure 9. Wire in place for Insertion

Figure 10 shows a wire in the process of being crimped into the terminal. While this is similar to the conventional crimping process, it is not a true crimped connection. In a true crimped connection the wire strands are stripped of insulation. The terminal crimping is done with a two piece crimping tool consisting of a punch and anvil. The resulting high pressure connection is very sensitive to crimping shape, dimensions and crimping force.

A true crimp connection does not lend itself to surface mount applications. It would be difficult to have uniform crimps because of the large variation in PCB thickness and solder thickness. In addition, the required crimping force needed to produce the high pressure connection would send undesirable compression forces through the PCB during the wire termination process.

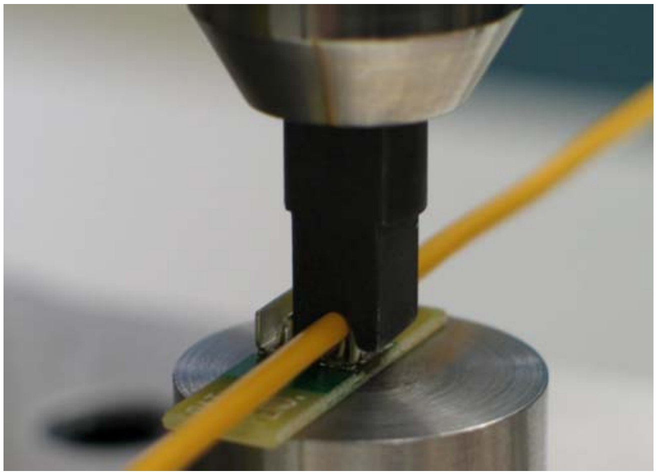

Figure 10. Wire is crimped into the terminal

The terminal being discussed here provides an insulation piercing connection. The cross section of the terminated wire is shown in Figure 11.

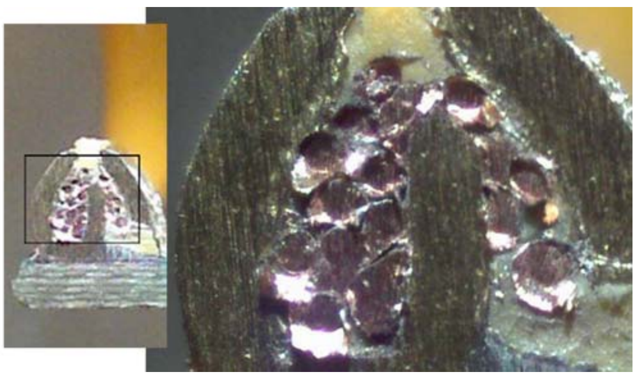

Figure 11. Cross Section of Crimped Wire

The insulation does not need to be stripped from the wire prior to termination. The connection is made by the insulation piercing spikes which are forced into the wire strands. The curved terminal "crimp ears" keep the spikes inside the wire and provide strain relief for the conductor. This insulation piercing process requires significantly less force to terminate a wire than conventional crimping, therefore shock loading of the PCB assembly is minimized. This process provides reliable connection through a large range of crimping forces so it is not crimping-force sensitive. It can accommodate variations of PCB and solder thickness.

In production there is no need for a separate step of placing the wire into the terminal. The terminal press automatically stitches the wire into the terminal. See Figure 12.

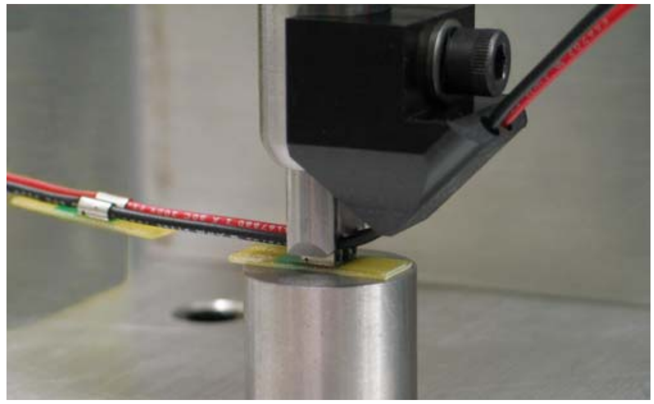

Figure 12. Stitching Press

While this method is a good economical solution for any application where a permanent wire connection is made to an SMT board, the largest interest shown has been from the LED lighting industry.

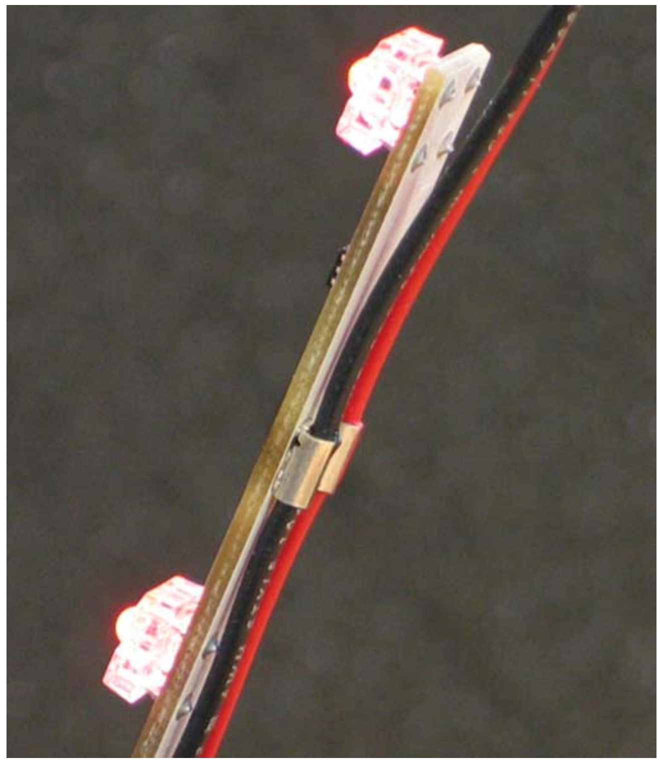

Figure 13. Channel Block Lettering Application

A channel block lettering application is shown in Figure 13. This method is especially well suited when the wire passes through the terminal and numerous serial connections are made to one single wire.

TESTING

As part of the validation process the following tests were performed: wire retention to terminal, terminal retention to PCB, current rating/heat rise, and thermal cycling and contact resistance.

Wire Retention to Terminal
The terminal was mounted to the PCB on the recommended solder pad using a .006" (0.15 mm) thick stencil and no-clean lead free solder paste. The wire used in the test was 18 AWG 16 strand wire with semi rigid PVC insulation.

a) Pull tests on ten specimens measured the straight axial tension load in pounds.

Force readings were: 16.90 (75 N), 17.70 (79 N), 19.02 (85 N), 21.90 (97 N), 18.70 (83 N), 17.90 (80 N), 20.70 (92 N), 19.30 (86 N), 18.90 (84 N), 20.90 (93 N).

Mode of failure was that the PVC wire and insulation tore while the crimped portion was retained in the connector. See Figure 14.

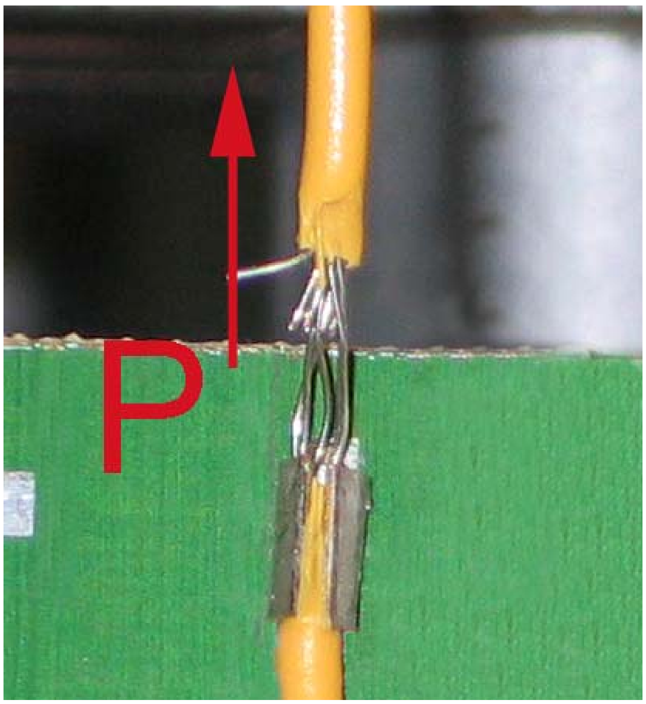

Figure 14. Axial Pull Test

b) Pull tests measured the radial tensile load perpendicular to the axis of the connector pulling away from the surface of the PC board.

Load data recorded was: 15.92 (71 N), 16.09 (72 N), 14.56 (65 N), 16.01 (71 N), 15.48 (69 N), 15.31 (68 N), 14.88 (66 N), 15.93 (71 N), 16.02 (71 N), 14.86 (66 N).
Mode of failure was that the PVC insulation stripped from the wire, and the crimped terminal deformed slightly during wire pullout. See Figure 15.

Terminal Retention to PCB
This test was performed two ways. One with the wire crimped in the terminal, the other with no wire crimped in the terminal. There was no difference in retention force of the crimped terminal and the terminal without wire, therefore the crimping had no effect on the terminal retention force.

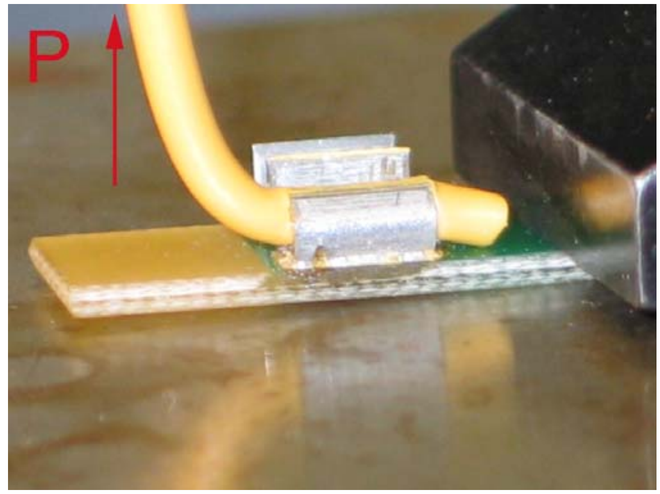

Figure 15. Perpendicular Pull Test

a) Push load was applied perpendicular to the axis of the terminal along the plane of the PCB while surface mounted to a printed circuit board, as shown in Figure 16.

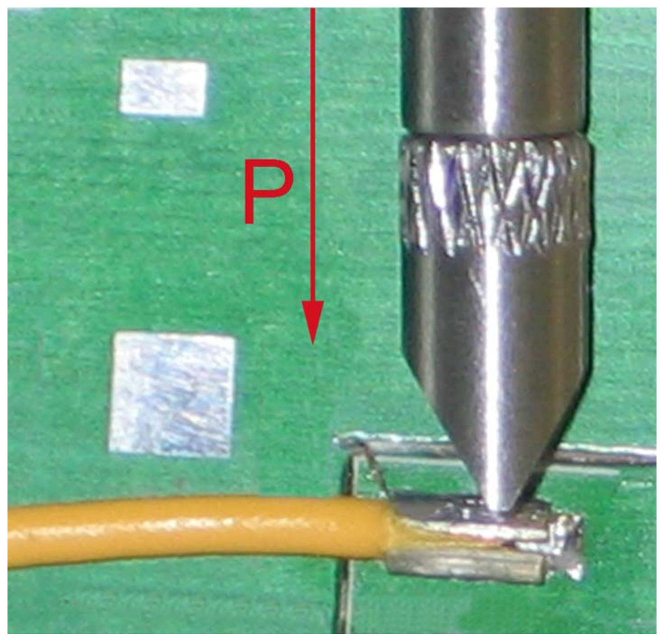

Figure 16. Terminal Retention, Lateral

Load data recorded was: 39.22 (174 N), 49.76 (221 N), 40.09 (178 N), 35.58 (158 N), 39.29 (175 N), 54.09 (241 N), 44.10 (196 N), 41.07 (183 N), 51.22 (228 N), 49.88 (222 N).

Mode of failure was that the solder joint failed. The copper pad remained on the board, and the terminal was not deformed.

b) Push load was applied along the axis of the surface mounted connector.

Load data in pounds was 21.56 (96 N), 22.49 (100 N), 32.52 (145 N), 30.19 (134 N), 30.91 (138 N), 38.48 (171 N), 29.99 (133 N), 31.19 (139 N), 29.58 (132 N), 32.11(143 N). See Figure 17.

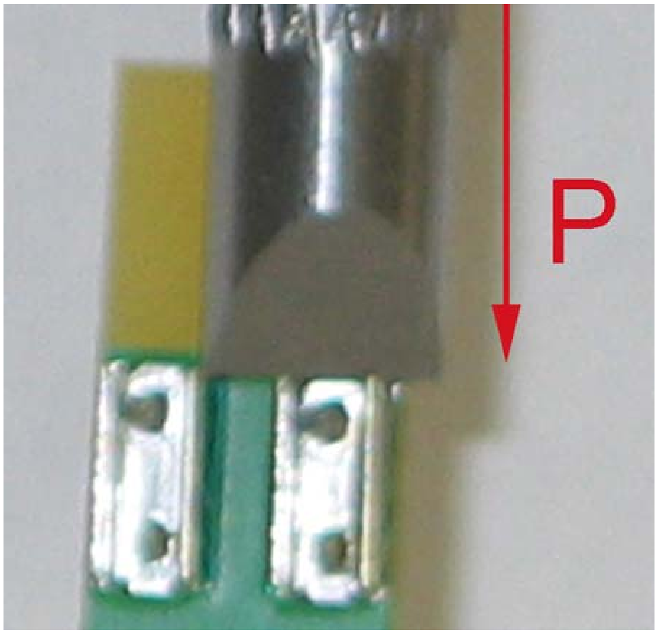

Figure 17. Terminal Retention, Axial

The acceptance requirement is that the terminal to PCB retention force must be at least 50% greater than the wire to terminal retention force. All the results exceeded that.

Ampacity Determination

The heat rise test was performed to determine electrical current limitations, in which similar to UL 310 standard, the current limit is established at 30 degrees Celsius rise above ambient.

Ten crimped terminal specimens were connected in series with 18 AWG stranded wire. The ambient temperature was recorded first at 23.8 degrees Celsius. The specimens were then connected to a power supply. Current was applied in increments, then left for a period of time for terminal temperature to stabilize. The temperature of each terminal was recorded with a thermocouple. Wire temperatures were recorded as a reference.

Table 1: Temperature Rise of each Connector (in Celsius):

Amps	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8
15	16.3	16.5	18.5	16.9	20.1	15.8	19.0	18.1
16	21.6	35.5	36.2	28.7	29.2	26.7	24.8	24.3
18	22.4	37.8	39.1	30.0	31.2	28.7	26.5	31.3

Recorded wire temperature @ 16 amps was 43.1 degrees C
Recorded wire temperature @ 18 amps was 49.7 degrees C

Conclusion: In review of the raw data per this test and test environment, it is recommended to apply a maximum of 15 amps to this connector. The ten recorded temperatures were well below the 30 degrees C. temperature rise for the applied amperage.

Thermal Cycling and Contact Resistance

Low level contact resistance measurements were performed on the surface mounted and crimped terminal before and after thermal cycling. Measurement points were near the edge of the solder pad on the PCB and on the wire at 1/4 inch from the terminal. The following are the actual readings in milliohms. No bulk resistance was subtracted from the reading.

Before thermal cycling: 9.0, 10.7, 11.0, 9.0, 10.5, 10.7, 9.5, 11.4, 11.2, 9.3.

Terminals were thermal cycled for 1,000 cycles. Because of the extreme temperatures, the actual test was closer to thermal shock than thermal cycling. The specimens were placed in a +90 degree Celsius hot chamber for one-half hour, then a shuttle mechanism moved them in one minute to the -50 degrees Celsius cold chamber where the specimens were kept for half an hour.

Resistance readings in milliohms after 1,000 cycles: 9.7, 11.5, 12.0, 10.0, 11.4, 11.8, 10.1, 12.5, 12.3, 10.2.

CONCLUSION

The Surface Mount Insulation Piercing Crimp Terminal is a reliable and efficient alternative to existing methods of wire to PCB termination.

ACKNOWLEDGMENTS

The author would like to thank the team whose contributions made this paper possible:
Sharon Harvey, Ron Fredriks, Ralph Tarulli, Carl Kriegeskotte, Eric Dubac, Roxanne Memmolo.

REFERENCES

[1] J. Legrady, "A New Type of Very High Reliability 'Torsion IDC' Which Can Accept a Large Range of Wire Gauges", Proceedings of Connector & Interconnection Technology Symposium, 1989, pp. 337.