# Circuits ASSEMBLY

JUNE 1996

## COMPONENT TECHNOLOGY TODAY

### CHANGING FORM TO FIT FUNCTION

A MILLER FREEMAN PUBLICATION

# A New Look at a Simple Design

By Gregory Torigian

## The terminal must lend itself to automatic PCB insertion and wire termination.

Insulation displacing connectors, or simply IDCs, have become popular because they provide a highly cost-effective method for performing wire terminations. They require no wire or cable preparation, and in the case of ribbon cable applications, they allow easy and effective mass termination of multiple wires.

Although conventional IDCs make good initial contact, they possess several flaws and limitations. The design of first-generation IDCs only allowed for peak application performance over an application range of one or, at the most, two wire gauges. In addition, engineers questioned the IDC's durability. PCB headers and connectors were preferred because of the IDC's inability to withstand the harsh conditions typical of industrial and automotive applications.

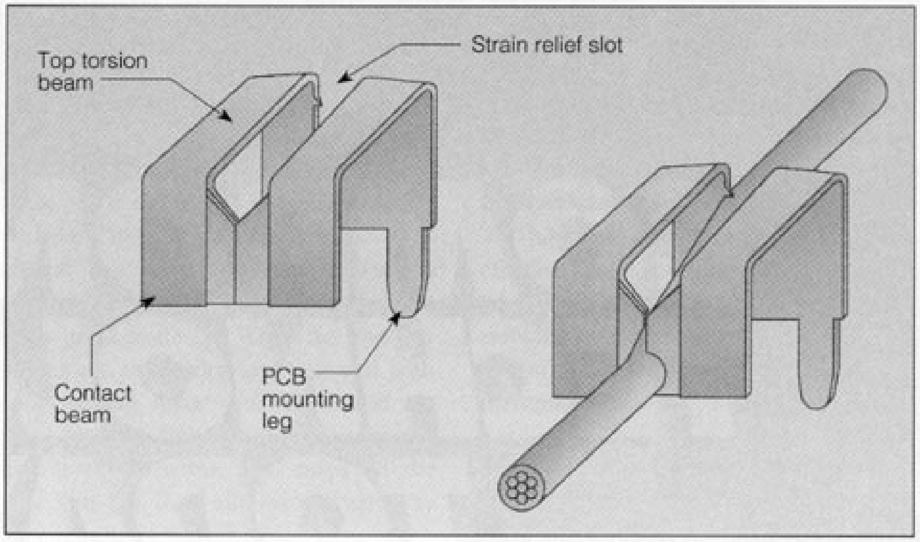


**FIGURE 1:** An IDC before and after wire insertion.

### Conventional IDCs

One of the major problems with conventional IDCs is that they typically accept only one gauge of wire, with a limited range of wire insulation material and thickness. This type of IDC consists of two fairly rigid contact beams with a U-shaped wire slot between the beams. Because the conductor slot is smaller than the conductor diameter, once a wire is inserted into the IDC slot, the lead-in chamfer cuts and displaces the wire insulation. As the wire is pushed further down in the slot, there is a deformation of the conductor and the IDC beam. The further the conductor is deformed and the contact is deflected, the larger the combined force exerted toward the connection interface. This force, called normal force, is critical in achieving a "gas tight" connection.

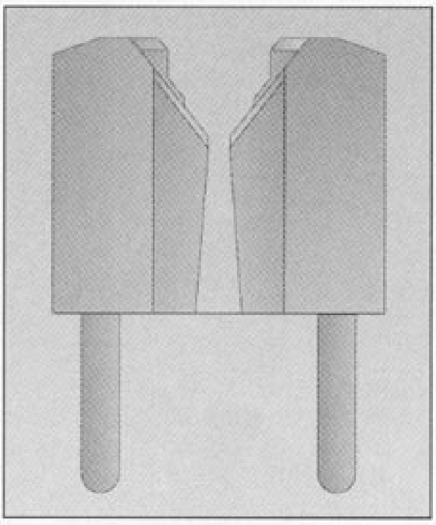

**FIGURE 2:** Loaded contact beam deflection.

**This new design represents a more effective method of achieving wire connection. Design engineers achieved a monumental task: overcoming formidable obstacles in component design, cost and market perception.**

## A Better Mouse

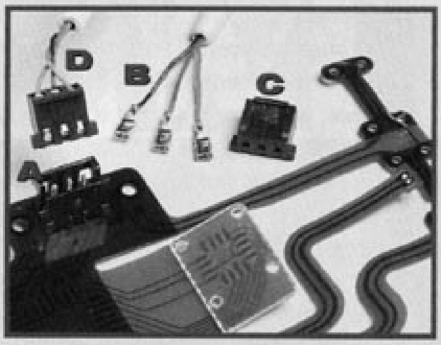


**FIGURE 1:** The "old" method of wire connection.

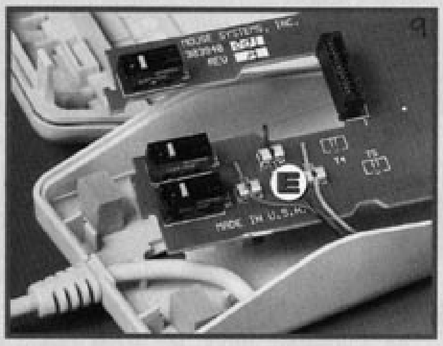


**FIGURE 2:** The "new" wire connection method.

Too often, new components and their ensuing costs escalate the price of developing new products. However, when Mouse Systems (Fremont, CA) recently developed an OEM optical mouse for computer workstations, the company was able to reduce interconnection costs by more than 50% using a new IDC design.

"When you manufacture a high-volume commodity product like a computer mouse, every penny you save results in substantial savings," said Ben Hayman, hardware development manager at Mouse Systems.

Figure 1 shows an example of the company's previous method of wire connection. This method required unnecessary components and operations. Prior to PCB connection, wires had to be stripped of insulation and crimped for insertion. Requiring a PCB header (A), the crimped wires (B) were then placed into the plastic housing (C). Finally, the stripped, crimped and housed wires (D) were ready for mounting and soldered onto the PCB. Total: four operations and three components.

Figure 2 shows an example of an installtion that required only the terminal itself (E). In this procedure, the need for and cost of PCB headers and connectors was eliminated. Also cable stripping, wire crimping, insertion and PCB soldering were compressed into a two-step procedure. Total: two operations and one component.

The conductor will primarily have plastic deformation, while the contact beams will have elastic deformation. This design is typically limited to one gauge of wire. It is extremely vulnerable to degrading mechanisms that work against the gas-tight connection and shorten the IDCs lifetime.

One such degrading mechanism is creep, defined as the change in deflection or deformation over time with constant force. Also referred to as sizing, which is the reduction of wire diameter due to environmental conditions, creep reduces normal force and wire connection reliability.

Another is stress relaxation, which is the reduction in force over time with constant deflection, largely dependent on initial stress level and temperature. Stress relaxation in the contact beams will reduce the normal force.

One final degradation mechanism is movement between the conductor and the contact. This is caused primarily by wire flexing and pulling, and the difference in the coeffficients of thermal expansion (CTEs) of the conductor and the contact material. Those movements are especially degrading in the case of standard wire because they help the wire strands to rearrange in a narrower shape with a lower energy level.

All these degrading mechanisms cause normal force reduction, depending on the contact spring rate. When a conventional IDC-terminated wire moves from shock or vibration, the wire tends to move out from the slot because it moves in the direction of least resistance. The short stiff beams of the conventional IDC have very little deflection, and after wire sizing, the normal force is largely reduced. Also, the stiff contact beams do a poor job of rearranging the wire strands into the narrowest width shape. The eventual presence of wire slippage, even occurring under rather typical conditions, dramatically reduces the connector's reliability.

### A New Design

In an effort to overcome some of these problems, design criteria were established for a new type of IDC. These criteria included:

- a separable connection that allows at least 10 mating cycles

• an ability to stand up well in a harsh operating environment, such as under shock, vibration, corrosive gas or high temperature

• a necessity to terminate several wire gauges (stranded and solid) while providing strain relief for the wire.

In addition, the terminal must lend itself to both automatic PCB insertion and wire termination and allow easy and reliable wire termination with a tool that provides positive wire feedback.

Figure 1 shows an example of this new IDC design mounted on a PCB—both before and after wire insertion. The two front contact beams are pushed against each other with a preset force called preload. Preload is set by forming the top torsion beams into a curved shape (crown) or by slightly curving the rear torsion beams and the rear base. Minimum contact force, the range of wire sizes and even wire strand rearrangement can be controlled effectively with the appropriate preload.

This design allows the wire insulation to be cut as the wire is pushed down against the coined V-shaped shear edges. As the wire is pushed further down, the wire termination slot will open up. This slot can open up to a width larger than the wire diameter without taking permanent set in order to receive the full diameter of the stranded wire. At this stage, the terminal beams are in a maximum force/maximum deflection position exerting high normal forces on the wire.

When the wire is moved further downward in the conduit slot, the high normal forces combined with the downward movement of the wire will rearrange the wire strands into their narrowest shape. The front contact beams will close in on the wire strands and keep them under contact pressure. Contact pressure can be set by the optimum combination of the preload on the two front contact beams and by coining the edges of the contact beams to adjust the contact area.

Figure 2 shows the deflection of loaded contact beams. Notice the slightly tapered wire conduit slot, which is widening at the lower part of the terminal. The angle of the taper can be adjusted by setting the preload correctly. As mentioned before, the preload is not uniform along the length of the wire conduit slot. It is larger near the insulation shear edges.

A slightly tapered wire slot can help improve the connector's reliability. For instance, in this case, if there is wire strand movement from the vibration or temperature change, the strands will move in the direction of least resistance, which is downward where the slot is slightly wider. The lower end of the slot is closed off by the surface of the PCB so the wire strands cannot leave the slot.

When a wire is inserted into the terminal, the wire insertion force is increased to the maximum, the insulation is cut and the wire opens up the wire slot. From this maximum level, the wire insertion force will rapidly decrease to a minimum while the wire is pushed down into the slot. This gives a snap-in effect. It is critical that when the wire is inserted with a hand tool (field termination), it gives good feedback. When the operator pushes the hand wire insertion tool with an increasing force, the wire should not move until the force reaches the termination level. Then the wire snaps all the way into the slot, eliminating half-way wire insertions.

On a conventional IDC terminal, the wire insertion effect is just the opposite. It takes an increasingly large force to push the wire all the way down in the wire slot because the wire gets tighter and tighter. When there is wire movement from shock, thermal cycling or vibration, the wire tends to move out from the slot because it moves in the direction of least resistance.

The rear slot on the terminal body uses two hooks or dimples to prevent the wire from coming out of the strain relief slot. This design also simplifies wire insertion during assembly by enabling the wire to be pushed in and seated in the strain relief slot by hand. This will keep a section of the wire lined up with the "V" groove of the insertion tool, which terminates the wire by inserting it into the wire slot.

Actual force displacement tests provided the results of conventional stress analysis and finite element analysis. Cross-sections of the termination showed the wire deformation range to be between 15 and 40%, depending on the wire sizes. With stranded wire, the deformation range is 5 to 15%. With seven-strand wire, the wire strands are usually rearranged into one single line, although not consistently because of other variables. When the wire is removed from the slot, the terminal returns to its original zero-gap position without the loss of the preload force between the contact beams, which is sufficient to maintain a good contact. Contact resistance measurements before and after accelerated aging and temperature shock show less than a 9% maximum change in contact resistance.

## Conclusion

This new design represents a more effective method of achieving wire connection. Design engineers achieved a monumental task: overcoming formidable obstacles in component design, cost and market perception.

*Gregory Torigian is the technical product manager with Zierick Manufacturing, Mt. Kisco, NY.*

(1) Janos Legrady,"A New Type of Very High Reliability 'Torsion IDC' Which Can Accept a Large Range of Wire Gauges", International Institute of Connector and Interconnection Technology, Inc., 1989 Annual Connector and Interconnection Technology Symposium.

(2) Edward Key, "A New Type of Insulation Displacement Terminal Which Can Accept a Large Range of Wire Gauges", ESCG Symposium, November 1983.

(3) Robert A. Wandmacher, "Insulation Displacement Connector Reliability", ECSG Symposium, October 1986.

(4) William J. Garver, "Mass Terminating Discrete Wire", ECSG Symposium, October 1979.