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Expert Contributions

1 What Is an Electrical Connector?

Robert S. Mroczkowski, a globally recognized connector guru, describes the function of an electrical connector in his *Electronic Connector Handbook* [1] as follows:

> "An electrical connector is an electromechanical system which provides a separable connection between two subsystems of an electronic device without causing an unacceptable impact on the performance of the device."

What is he trying to tell us?

First of all, we must realize that a connector is rarely an optimal solution to a problem. When using connectors, a compromise must always be made—be it in the mechanical design or for the electrical signal routing.

With this in mind, an attempt is made to design an electrical connection with regard to impedance, frequency characteristics, contact resistances, and service life expectations in such a way that the requirements of the overall system are met from an economic point of view.

As the separation points must also meet physical (mating cycles, shock, and vibration) and chemical (corrosion) requirements, copper-based contact materials (conductivity) such as brass, phosphor bronze, or nickel silver must be provided with surfaces that achieve the lowest possible contact transfer resistance with simultaneous corrosion resistance and abrasion resistance over the service life of the overall system.

These compromises will continue to accompany us in the future. Many users think that a manufacturer will design a connector specifically for their application. Even if the user pays tooling cost, this is only feasible in the rarest cases. The manufacturer will investigate the market to see whether such applications occur globally. And even if they do, they will be reluctant to agree, because the development of a new connector nowadays runs into the millions and, on the other hand, the user will sooner or later demand a second source, whether for reasons of price control or really for reasons of security of supply.

Why are new developments of connectors so expensive? Because the customer demands an optimum product with reproducible quality that can no longer be manufactured by hand but must be produced using camera-monitored punching tools, integrated injection or overmolding tools, and fully automated assembly tools.

It therefore makes sense for the user to focus on existing products. Sometimes it is small things, such as temperature ranges, that prevent the use of existing products. In such cases, the user should definitely talk to the manufacturer, because products are developed for a specified market and this market may have lower requirements than the current application.

In such cases, the manufacturer may give its approval, even if this is not reflected in a revised product specification. A new product specification would also mean a new product qualification, which in turn is very cost-intensive.

TIP

If you are interested in the process of connector qualification and fault patterns, read expert contribution 1 titled "Qualifying and Evaluating Connectors" in this book.

In Brief

An optimal selection of a product for a specific application is important in order to find a cost-effective solution for the existing connector problem. This book is intended to help you with your selection and decision.

2 Connector Components

If we look at an electrical connector in detail (Figure 2.1), the following individual parts must be taken into account:

- Termination technology pin contact
- Insulator pin contact
- Base material pin contact
- Surface pin contact
- Surface socket contact
- Base material socket contact
- Insulator socket contact
- Termination technology socket contact
- Shielding of the electrical connector (- - - -)
- Housing and locking mechanism

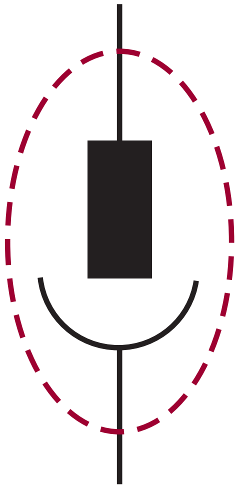

Figure 2.1 *Elements of an electrical connector*

First, let’s look at the termination technology; we typically distinguish between

- Soldering,
- Welding,
- Screws,
- Press fit,
- Crimping, and
- Insulation displacement connectors.

3 Different Termination Techniques

When soldering, we distinguish between soldering into, soldering through, soldering on top, and soldering on wire.

3.1 Soldering Into

Soldering, especially wave soldering, is used to solder a wired component into a single-layer printed circuit board (PCB), for example. This technology is rarely used today. Exceptions are PCBs that are installed in simple household appliances, hobby tools, or similar.

3.2 Soldering Through

Through-hole soldering is a technique in which the solder paste is applied over a plated-through hole (PTH), into which a wired component is then inserted, and subsequently soldered during the reflow process. This technique is also known as **pin-in-paste** (PiP) or **through-hole reflow** (THR) and requires that the circuit boards have PTHs and the components are reflow-capable, i.e. they can withstand temperatures of +260 °C.

It must also be taken into account that the solder paste applied over the PCB is large enough (often limited by the contact pitch minus 0.2 mm separator in the stencil) to fill the space between the PTH and the component's pin. The calculation must take into account the shrinkage of the solder paste (~50% of the volume) during the reflow process.

Further boundary conditions are a distance of 0.25 mm between the connector housing and the circuit board in the area of the solder paste application (plastic feet as spacer) and a maximum penetration of the connection pins underneath the circuit board of 1 mm. This prevents solder paste from accumulating at the end of the pin, which would then be missing in the soldering area.

Finally, it is appropriate to deliver these components in tape and reel so that they can be assembled fully automatically using pick and place machines.

3.3 Soldering on Top

Soldering, usually referred to as surface-mount technology (SMT), is the state of the art today. SMT has the advantage that conductive tracks can run under the component in multilayer PCBs and that the B-side of the PCB can also be fitted with components.

The PCBs are printed with paste using stencils, and then the components are placed and finally soldered using the reflow process.

The component manufacturer specifies the layout for the solder pads. The size of the paste print is usually defined by in-house guidelines, which also take solder resist, etc., into account.

SMT is limited to component lengths of a maximum of 50 mm because PCBs can inflect during the reflow process, resulting in open solder joints on larger components. If larger than 50 mm components need to be processed, press-fit technology or the PiP/THR process is suitable.

In addition to soldering, connection pins can also contact PCBs using press-fit technology.

3.4 Press-Fit Technology

Press-fit technology has its origins in the 1970s, when assembly systems for telecommunications and military applications were still wired to the backplane using wire-wrap technology. At that time, solid posts were pressed into PCBs with plated through holes (PTHs). It quickly became clear that this technique would put a lot of stress on the PCBs—especially because repair options for any damaged connector pin also had to be taken into account.

Flexible press-fit zones were therefore developed. In the 1990s, more than 20 different designs competed for the PTH with a diameter of 1.05 mm, and each connector manufacturer claimed that their design was the true one.

At that time, the connector pitches were 2.54 mm or 2.50 mm. Due to the ever-increasing packing density, the hole diameters had to be reduced, and today, press-fit technology is mainly offered as a punched *eye of a needle* (EoN) for hole diameters from 0.31 mm to 1.05 mm. The hole diameters are referred to as *finished hole diameters* (PTH). In the lead-free age, the originally large hole tolerances are no longer required; chemically tin-plated or *Electroless Nickel Gold* (ENIG) PCB surfaces are used, and PCB manufacturers know that the finished dimensions of the PTHs must be in the upper range of the tolerance band, because chemically tinned surfaces are rougher than the previous lead-containing *hot air leveling* (HAL) surfaces and therefore the press-fit process can be critical in the lower diameter tolerance band.

TIP
Expert contribution 2 titled "Press-Fit Technology" in this book provides detailed information on this technology.

The following sections describe the connection of wires, strands, and cables to electrical connectors.

3.5 Soldering on Wires

This is the traditional soldering process using a soldering iron and solder wire. The pre-tinned stranded wire is inserted into the solder pot or inserted through the soldering eye and soldered by adding solder wire. Soldered connections of stranded conductors must also be fitted with a bend protection sleeve (heat shrink tubing), as otherwise individual strands may break off behind the solder joint when the stranded conductor is bent. Shield connections should be made with copper foil and filler wire.

In addition to soldering, wires can also be welded, screwed, or crimped on.

3.6 Welding on Wires

Welding wires—whether by resistance welding or ultrasonic welding—is a complex process, but one that can be automated. Welding is always used when the contact resistance of a crimp connection is either too unstable (e.g. in the case of an ABS -- antilock brake system - sensor that is exposed to high vibration) or too high (e.g. in the case of stranded conductors that are above 25 mm^2 in high-current applications).

3.7 Screwing on Wires

Screwing on wires is not only used in installation technology. More and more terminal strips for electronic circuit boards are being used—both as one-piece terminal strips and in two-piece versions, each with soldered pins. With regard to the screw, it is important to ensure that the clamping point does not damage the stranded conductor (i.e. no screws are directly placed on the stranded conductor) or that ferrules are used.

A simpler way to terminate wires is to use cage clamps. Depending on the design and cross-section, there are cage clamps for direct contacting (simply insert the wire) or, for larger cross-sections, with locking and unlocking levers.

3.8 Crimping on Wires

Crimping contacts to wires is certainly the most widely used connection technique. The wire is inserted into a stripper crimper and a contact (preferably with a wire crimp and insulation crimp) is applied directly to the end of the wire. The bundle of crimped contacts is then snapped into the correct positions of the connector housing manually or with the help of color recognition of the wire insulation with an automated machine. If the contact does not have an insulation crimp, a bent protection sleeve (heat-shrink tubing) must also be applied here!

Wire cross-section (mm^2 or AWG), crimp contact, and tool setting must be matched to each other.

As crimping is a type of cold welding of the individual wires of a stranded conductor, the crimp machine must be monitored regularly by checking the height and width of the crimp and by measuring the pull-off forces.

Crimping involves cold welding of the stranded wires, which is why tin bronze is preferable as contact material. Brass creates microcracks during crimping, which can lead to corrosion in the long term.

Solid wires cannot be processed in crimp contacts as there is no cold welding!

TIP

Expert contribution 5 titled "Component Design for Automated Wire Harness Production" in this book provides detailed information on this technology.

3.9 IDC Technology

With an insulation displacement connection, several wires—preferably from a flat ribbon cable—are connected to a connector at the same time. The wire cross-section and contact fork must be precisely matched. The impact strength of the wire insulation also has a significant effect on the quality of the insulation displacement technology.

Shielded ribbon cables are expensive and difficult to process, which is why round cables are offered that have twisted wire pairs inside. A simpler solution is to use additional ground wires in the ribbon cable, which allows acceptable shielding to be achieved over short distances (Figure 3.1):

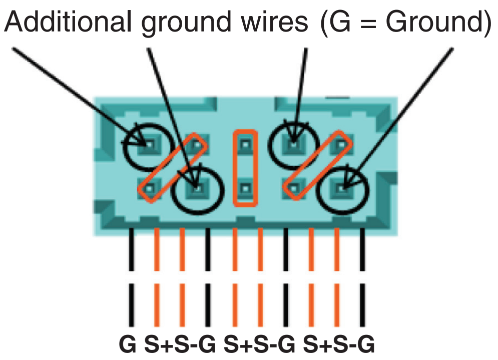

Figure 3.1 *In this arrangement, the differential pairs of a ribbon cable with 1 mm pitch have 105 Ω impedance!*