MAXIMUM SOLUTIONS

Product Reliability Builds on Robust Interconnect Solutions

Connectors play a critical role in electrical systems of just about any product we can imagine. However, the interconnect requirements are frequently considered at the end of the product design phase. The impact of an interconnect is often appreciated only when poorly manufactured or incorrectly specified connectors fail, eroding system performance at a minimum and even bringing the system to a halt. For designers, however, advances in connector design, materials, and manufacturing ensure availability of an interconnect solution well matched to each individual application.

The quality and reliability of interconnect directly influences system performance and reliability as a whole. Indeed, the selection of a suitable connector depends on a design's performance requirements, configuration limitations, operating conditions, and working environment. For example, the connector requirements for a healthcare application are dramatically different from those for a deep mining application — yet each requires maximum reliability from the connector.

If connector selection is not given proper consideration, the entire application can be left exposed to performance and reliability breakdowns. In fact, today's innovative connectors are high-precision pieces, carefully designed and manufactured using a variety of high-conductivity alloys, application specific platings and high temperature, high strength housing materials.

One of the main components of connectors and discrete interconnect systems is the pin receptacle. Pin receptacles are made by press-fitting stamped and formed "multi-finger" precision contact clips into a machined shell (*see Fig. 1*). This style of contact has proven to be an extremely reliable and consistent way to connect critical components.

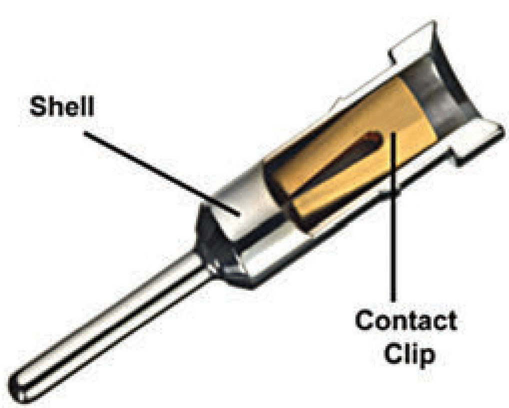

Fig. 1: Precision pin receptacles combine a precision-machined shell with a contact clip designed to provide a gas-tight connection. (Source: The Mill-Max Receptacle – Connect with Confidence Paper)

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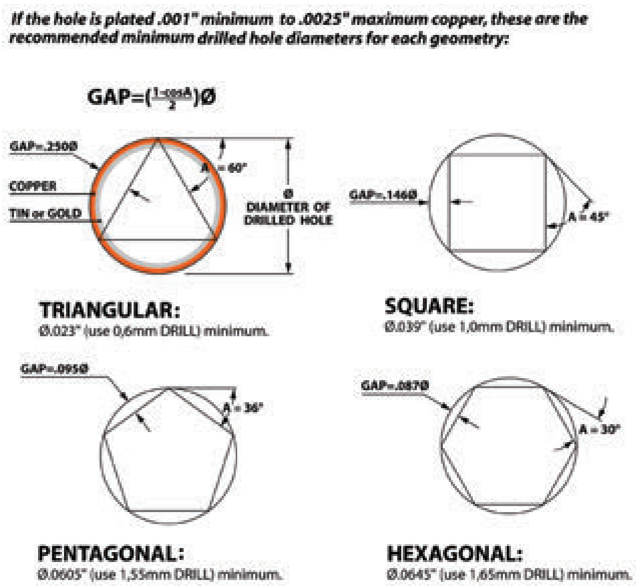
Manufacturing and materials

The receptacle itself is a product of precision machining and specialized alloys designed to match specific application requirements. For precision connector lines, high-speed Swiss turning and CNC machines produce parts across a wide range of sizes while holding very tight diameter tolerances of ±0.0005 in. and even tighter for some applications. Internal stamped finger contacts provide connections for mating leads ranging in diameter from 0.008 to 0.102 in. as well as square and rectangular pins.

Using advanced machining capabilities, interconnect manufacturers such as Mill-Max can offer receptacles with many termination styles, including press-fit, solder mount, compliant press-fit, swage mount, and wire termination options including solder cup, crimp, forked, and bifurcated. These same manufacturing capabilities allow creation of specialized receptacles suitable for pressing into plated-through holes in printed circuit boards. Here, polygon press-fit features such as a square, hexagon, pentagon, or octagon are machined on the body or tail of the receptacle — providing stress relief when pressed into the plated through-hole on a PCB. Press-fit features are typically held to a tolerance of ±0.0005 in. to help maintain consistency during the press-fit operation, which is especially important if the application calls for solderless press-fit.



While precision manufacturing allows for a wide range of shapes and sizes, the materials used for interconnect manufacturing endow these parts with specific performance and manufacturability characteristics optimized for different application requirements. A variety of alloys are used in the manufacturing of machined electrical interconnects - mainly copper based due to their high conductivity - from highly ductile brass to high strength beryllium alloys.

Brass is most commonly used as it exhibits excellent machinability, is suitable for a wide variety of applications, and is cost effective. Phosphor bronze is a more ductile material, useful when additional strength and bending resilience are required. For higher current applications, tellurium copper's high conductivity (93% IACS at 68°F) characteristic provides a low-resistance electrical path producing less temperature rise.

Depending on the desired size and force characteristics, the internal contacts are three-, four-, or six-finger designs stamped from either beryllium copper alloy C17200 (HT) or beryllium nickel alloy 360. Beryllium copper has emerged as the standard for the majority of applications thanks to its excellent strength, spring characteristics, durability, and conductivity. Beryllium nickel exhibits similar properties and is particularly suitable for use in high-temperature environments above 150°C.

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Critical healthcare

State-of-the-art connector technology provides options designed to meet specific performance and configuration requirements in applications as diverse as healthcare, LED lighting, and those in rugged environments. More specifically, the combination of a precision machined outer shell and stamped internal finger contact provides the flexibility, quality, and reliability required for mission-critical applications.

In the healthcare industry, high-reliability receptacles are used on detector boards for CT scan equipment; in I/O connectors for portable blood analyzers and implantable devices for data acquisition and transmission; for socketing transducers that monitor and regulate vital signs, blood sugar, and other bodily functions; in the signaling circuits for medicine delivery pumps; as the power jack for medical and dental drills and saws; and in cables used on a variety of medical equipment and devices.

Pins and receptacles are often the building blocks for these interconnect systems. A typical healthcare interconnect application has the need to terminate fine gauge wires to male and female components to make up cable assemblies. Mill-Max addresses this need with accurately machined pins and receptacles featuring wire termination options such as solder cups or crimp barrels. The receptacle is fitted with a high reliability beryllium copper spring contact able to make a secure electrical and mechanical contact to the mating pin. All the components are gold plated to provide protection, durability and reliability (*see Fig. 2*).

Fig. 2: Manufactured using precision turning technology, pin/socket interconnect pairs support high-density grid applications such as the termination of medical cables. (Source: Maximum Solutions – Micro-Interconnects for Medical Cable Applications)

This receptacle design of the machined shell fitted with the beryllium copper contact provides a gas-tight connection at the interface of the mating lead and the internal spring contact. This gas-tight connection secures the interface against potential oxide-forming environmental conditions and helps reduce the effects of fretting corrosion that can otherwise occur in these applications.

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As with other mission-critical applications, healthcare systems present exacting requirements for interconnect design and performance, putting a premium on versatility & dependability. To meet this demand, interconnect systems such as Mill-Max's offer designers a selection of 39 internal contacts to address specific requirements for lead size, insertion/extraction force, and temperature.

LED lighting

While healthcare systems present multiple critical requirements, applications for LED lighting in aerospace, transportation, and other areas are no less demanding. In these applications, precision interconnects are used in control circuits, cable-to-board power connections, board-to-board daisy chaining, and communications.

Interconnect manufacturers such as Mill-Max address evolving LED lighting requirements with products such as receptacles and sockets suitable for LED bi-pin bulbs and interconnects ideal for coplanar mating of LED driver boards, as well as a variety of through-hole and surface-mount options.

LED lighting applications, such as strip lights, often require end-to-end mating (daisy chaining) of boards. For these configurations, designers can find through-hole and SMT interconnect solutions. Horizontal surface mount (HSMT) connectors are particularly suited to these applications (*see Fig. 3*). Available grids as fine as 0.050 in., these headers and sockets typically offer Z-bend-style lead terminations, providing a low profile and easy inspection of solder joints.

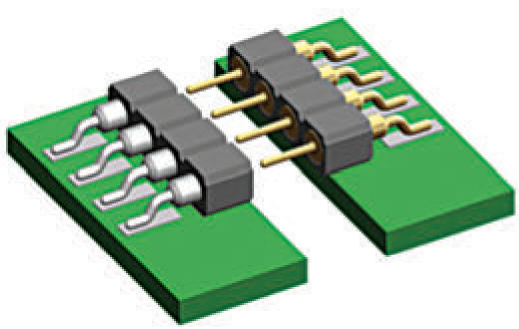

Fig. 3: The horizontal-mount headers and sockets of Mill-Max machined pin interconnects can be used for making LED driver board connections. (Source: Mill-Max Connectors suitable for LED Lighting Applications)

Other available solutions include spring-loaded products in single-row strips as well as a low-profile surface-mount header with Z-bend SMT terminations on both ends, which is useful for creating a soldered, daisy chain connection of two coplanar boards. This type of connector is particularly convenient when access is only available to the top of the board or when a permanent connection is desired.

Rugged connectors

Equipment designers and their customers expect high-quality interconnect solutions able to maintain robust connections regardless of environmental conditions and usage. Underlying high-reliability interconnect systems, advanced manufacturing methods build in strength and performance. For example, after stamping and forming, connector contacts are heat treated to yield contacts with excellent stress relaxation properties — defined as the resultant loss in spring force with time at constant strain and elevated temperature.

An interconnect's stress relaxation characteristic is key for both high cycle life — repeated insertions and extractions — as well as stationary mating scenarios where a connection faces extended exposure to harsh environmental conditions or shock and vibration. Typically, high quality interconnects are able to withstand 15-G vibrations and 50-G shocks with no electrical discontinuity greater than 1 µs.

High-reliability receptacles are ideally suited for socketing sensitive devices such as gas detectors, transducers used in seismic recorders, temperature and pressure sensors like those found in downhole and underwater exploration as well as inspection equipment and robots. Bulb sockets often utilize these types of high-precision receptacles, particularly in safety equipment such as flashlights and lamps used by the military, law enforcement, firefighters, and the mining industry. With their likelihood of high shock and vibration events, rugged environments also call for dependable connections and precision receptacles for applications as diverse as the firing mechanism of smart bullets, military radios, sighting scopes, field data recorders, ruggedized computers, sockets for aerospace dashboard displays, and nail guns for construction.

Although beryllium copper is the default material for standard internal spring contacts for receptacles, applications exposed to high temperatures can take advantage of more temperature- and force-resistant materials. For applications such as downhole oil and gas exploration or test and burn-in systems, where the ambient operating temperature is above 150°C, beryllium nickel is the material of choice for contacts. Beryllium nickel exhibits little or no stress relaxation when exposed to 225°C for 1,000 hours (*see Fig. 4*). Along with high-temperature performance, beryllium nickel contacts inherently withstand higher forces.

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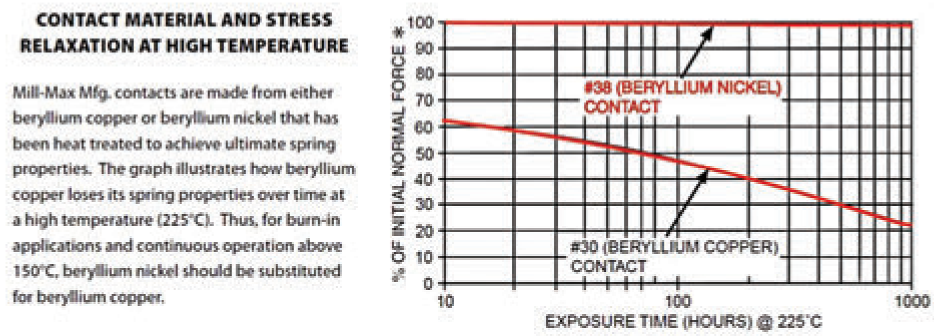

Fig. 4: Beryllium nickel exhibits little or no stress relaxation when subjected to extended exposure to high temperatures — a critical characteristic for applications operating in harsh environments.
(Source: The Mill-Max Receptacle – Connect with Confidence Paper)

Interconnect flexibility

In more advanced interconnect systems such as Mill-Max's, beryllium nickel contacts fit into the same receptacle shell as their beryllium copper counterparts and can be specified as a design evolves from the workbench to the field. In fact, this type of configuration flexibility is increasingly important to designers. With more sophisticated interconnect solutions, engineers can test their interconnect designs, modify interconnect strategies, and even switch to different connector materials and sizes without redesigning the overall interconnect design.

For applications requiring optimal environmental protection or for PCB press-fit applications, gold plated shells and contacts are typically the right choice. Because both the outer shell and internal contact are individually plated in interconnect systems such as Mill-Max's, the design engineer has the flexibility to choose tin, tin/lead, gold, or silver plating based on economic and engineering considerations. For example, tin or tin/lead-plated shells with gold-plated internal contacts are a cost-effective option for solder mount receptacles accepting gold-plated mating leads. Despite the different combinations of metals, the gas-tight press-fit between the contact and shell eliminates the chance of oxidizing interactions. This gas-tight connection ensures that no corrosion arises at the contact-shell junction due to environmental conditions such as high humidity or exposure to gases.

In addition, interconnect platforms such as Mill-Max's allow designers to change pin sizes thanks to the wide mating lead acceptance range built into these products. While some interconnect systems have a fairly tight lead acceptance range of 0.004 in., enhanced interconnect contacts such as Mill-Max contacts have a much greater range, generally 0.010 in., with larger contacts enjoying a range up to 0.020 in. in some cases. The wide acceptance range of receptacles translates into greater tolerance on the mating lead size and position — a useful option when a device, mating board, module, or cable undergoes an unexpected change in pin design or specification. Thus, if a piece of equipment is initially designed to receive a cable of a particular size and that cable is revised to use larger or smaller pins, the wider acceptance range available in a versatile receptacle design may easily support the change in specifications.

A flexible interconnect platform also allows engineers to choose higher- or lower-force contacts for most mating lead sizes. In the Mill-Max system, for example, 32 of the 39 contacts have at least one alternative force option. Lower forces are desirable for applications such as high-pin-count interconnects; delicate, soft, or flexible leads or wires; socketing leaded glass-sealed (hermetic) devices; and to ease field replacement and repair in tight spaces.

Conversely higher forces are desirable for ruggedized applications facing high shock and vibration, fretting corrosion, high-current connections, and long-term static connections. In addition, higher-force connectors can help overcome oxides caused by environmental conditions, which is especially advantageous in circuits with low currents.

Conclusion

Interconnect quality and reliability play a fundamental role in determining overall system quality and reliability. For designers, highly developed interconnect systems provide a broad array of solutions, precision-machined from alloys designed to meet varying needs for ductility, manufacturability, strength, and temperature resistance. Drawing on these precision parts, engineers can create an interconnect solution optimized for the unique requirements of each application.

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