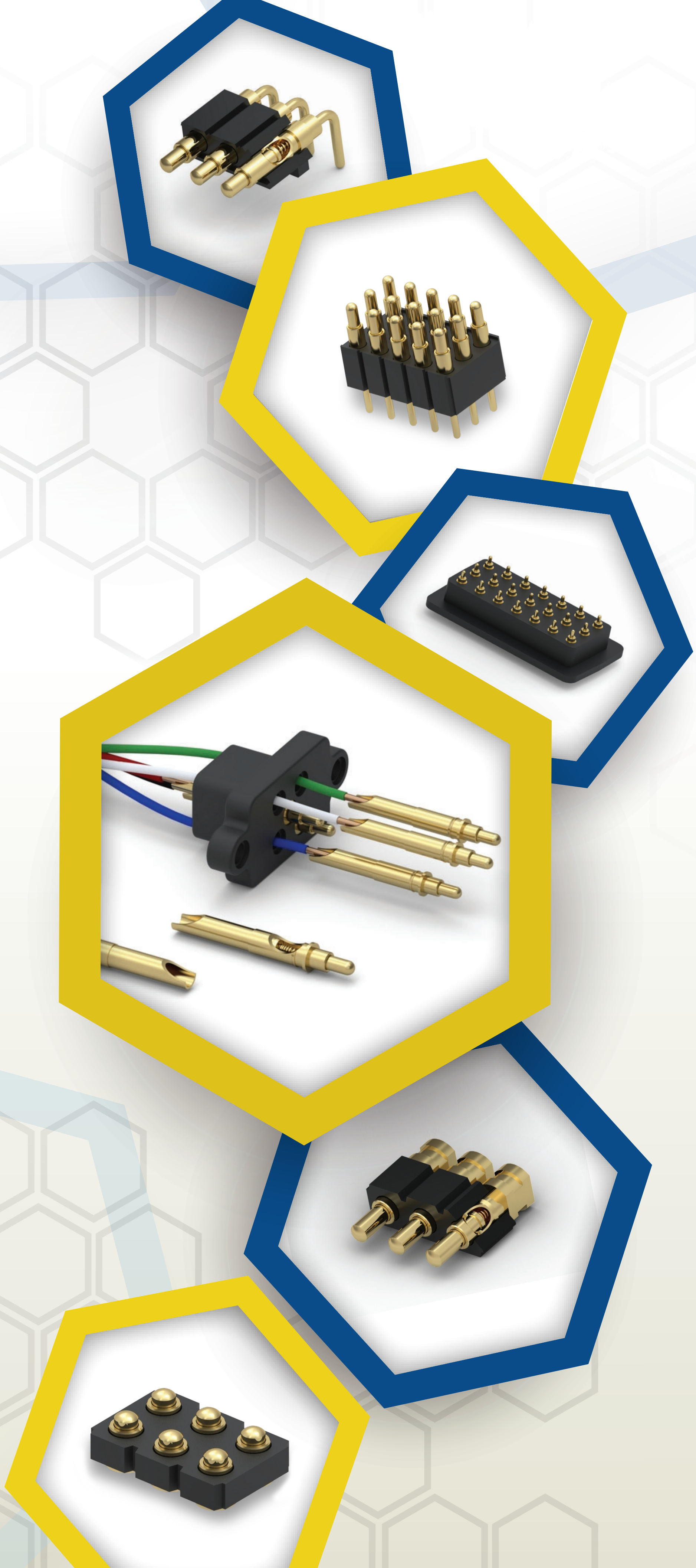

How to Select the Correct Spring-Loaded Connector for Today's Interconnect Applications

High-quality precision-machined contacts offer multiple solutions for critical design challenges

By: Stephen Capitelli, Mgr of Product Engineering

Much of the focus on modern portable devices relates to their increasing functionality, lifetime and convenience of operation. This would not be possible without the availability of highly reliable and proven connector technologies that facilitate miniaturization and connectivity.

In this white paper, Mill-Max Mfg. Corp. will look at the fundamentals of spring-loaded connectors (SLCs) and how to specify them for optimum performance in modern applications. The paper describes methods by which manufacturers assess and demonstrate reliability as well as considering some novel ways in which SLCs have enabled applications.

The Challenge of Connecting Correctly

In the world today, very little has great value in isolation. Connectivity is crucial for so many aspects of modern design, technology and life. The greatest challenge facing designers is achieving the right balance between reliability, suitability and cost. In order to begin the search, the application and the requirements that it will put upon the connector(s) needs to be fully understood.

In some applications, the connector is mated once during production. In others the connector is an integral part of the device, such as in a docking station or a charger. Each of these applications has different challenges and requires a different solution with regard to the design and the materials used.

While connectors are often seen as 'simple', a correctly applied connector will function better – and last longer – than one that is not well suited for the application. Gathering and using this knowledge is another connector-related challenge for today's designers.

Precision-Machined Technology

There are several methods for creating the pins used in connectors. The most flexible is precision machining. This not only provides high levels of quality and reliability, but also offers significant flexibility in terms of design and materials, allowing designers to specify connectors to suit their exact needs. The resulting high-precision pins have a basically cylindrical geometry and are sometimes called 'turned' pins.

Typical turned pin sizes range from 0.008" (0,2032 mm) to 0.250" (6,35 mm). High-speed turning can consistently produce precision-machined pins to tight tolerances of +/- 0.0005" (0,0127 mm) across these sizes on all critical features that are essential to the functionality of the pin as a connector. Not only is the process highly accurate, repeatability is excellent – whether a thousand or a million pins are being manufactured.

Figure 1: *Components of Spring-Loaded pins are machined to extremely tight tolerances to produce high quality, reliable spring pins*

Specifying Spring-Loaded Connectors (SLCs)

The main component in the SLC are the Spring-Loaded pins, sometimes called Spring-Loaded contacts, Spring probes, or Pogo Pins, that provide a highly reliable, precision-made interconnect solution ideal for a wide variety of demanding applications. Each spring-loaded pin is precision-machined to ensure a high quality, low resistance and compliant connector, thereby giving it the edge over other technologies.

Figure 2: *The spring is the critical component in an SLC*

Figure 3: *Spring-Loaded pins are available in many shapes & sizes to suit a wide variety of applications*

Spring-Loaded pins typically comprise three or more separate machined components that are assembled with an internal spring to provide the range of movement required. All of these components are electroplated with gold over nickel to ensure excellent electrical conductivity, durability and corrosion protection throughout the life of the product.

Beyond the basic electrical requirements of voltage capability, current handling and contact resistance of the Spring-Loaded pin, there are many options available that require consideration when specifying SLCs.

While vertical mounting is the most common arrangement, the form-factor of certain applications means that horizontal mating of two (or more) boards is desired. Right-angle pins and targets that are available in both through-hole and surface-mount configurations on a 0.100″ (2,54mm) or 0.050″ (1,27mm) pitch offer a low profile and reliable solution to this challenge.

SLCs are often required to carry both power and signals within the same assembly. Standard power pins can carry currents up to 9 Amps with only a 10°C temperature rise above ambient (20°C). Where higher current (or lower temperature rise) is required, pins may be doubled up, or larger pins can be specified, especially for ground connections.

By specifying spring pins with different lengths and plunger travel in an array, so-called 'make-before-break' connections can be created. This is especially useful where power needs to be applied to a circuit before signal connections, thereby avoiding undefined states that can cause erratic behavior in the application. This also enables key signals, such as enables, to mate sooner or later, based on the requirements of the application.

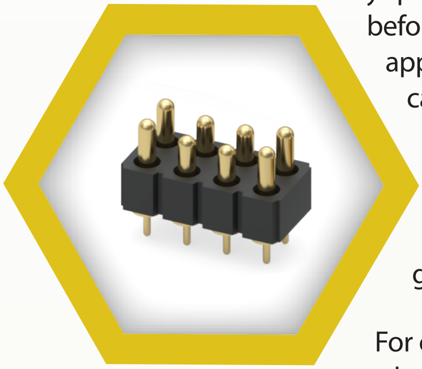

Figure 4: *Spring-Loaded pins can be specified in an array with different heights to create "make first-break last" connections*

Depending upon the mechanical configuration of the application, different travel distances may be required, along with custom spring forces. Most SLCs typically offer 60 grams of force at mid-stroke, although alternate springs are readily available.

For complex, multi-board assemblies, double action SLCs are available. Once these are fitted to the middle board in a stack, then boards may be easily and conveniently mounted above and below.

SLCs are not limited to PCB-oriented applications. This versatile technology extends to providing connectivity for wire termination through the availability of pins with solder cups or crimp barrels. Various sizes are available offering the ability to accommodate wires up to 16 AWG, with 9 Amp current handling capability.

Where the connections are required through metallic or conductive materials (such as passing through a conductive case or housing) then individually insulated SLCs are available with a high temperature Nylon 46 insulator that is compatible with most soldering processes.

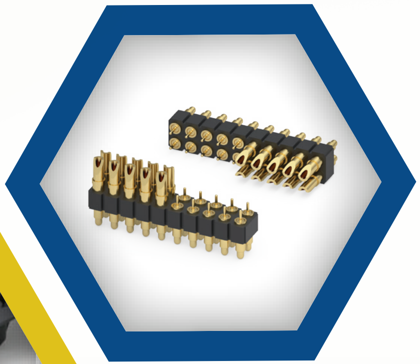

Figure 5: *Complex arrays of dissimilar pins can be created easily*

When designing in an SLC, it is generally best to aim to operate around the mid-stroke of the travel range. Between 25-75% compression is recommended, although some 'one-time compression' applications benefit from working closer to the maximum compression. For very low profile spring pins with minimal stroke capability it is best to be in the 50-85% compression range.

Figure 6: *Individually insulated SLCs for connecting through conductive materials*

Spring pins are able to mate with non-parallel surfaces, but it is important to ensure that the mating force is applied axially to the piston/plunger. Lateral engagement or side-loading of the piston should be avoided since this may cause damage to the piston or spring pin body by bending or fracturing it.

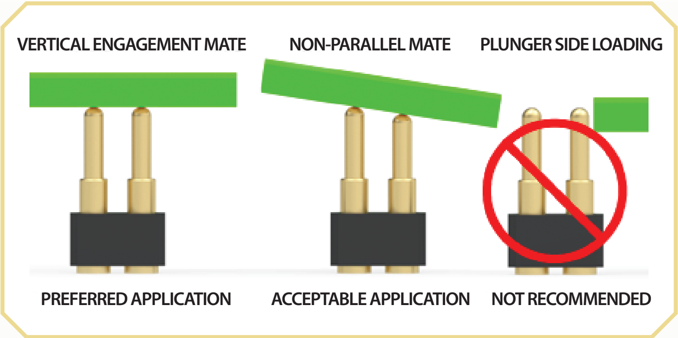

Figure 7: *Non-axial forces should be avoided to avoid damage*

In some applications where mating is less controlled, it is good design practice to incorporate stand-off hardware or other features to provide mechanical support, thereby avoiding over-compression of the spring pin.

One of the great benefits of SLCs is their versatility and ability to mate with a wide variety of surfaces. Provided the spring pin plunger/piston makes contact with a flat or concave plated surface, then a good connection is made. This removes one side of traditional 'pin and socket' connector systems and leads to cost savings in terms of component cost and production time and complexity.

Figure 8: *Surface-mount concave targets provide an ideal mating surface*

While mating with gold-plated PCB pads is the most common implementation, other mechanical options are available to meet specific application requirements. For through-hole applications a dedicated nail head pin or target pin can be used. In surface-mount applications, low-profile, gold-plated target discs are available to provide a highly conductive, wear resistant extension to the board surface. By combining spring pins with the appropriate target, different mating distances can be implemented to suit almost any application.

Proven Reliability

Poor quality connections, either through poor design or through wear-and-tear in long-term usage negatively impact the overall system reliability. As such, proven and demonstrated reliability is crucial to specifying the correct SLC for an application.

IEC 60512, Connectors for electronic equipment - Tests and measurements, has been the definitive standard for testing connectors for their mechanical, electrical and climatic properties since its introduction in 1976. The standard prescribes a number of tests to assess the quality and reliability of connectors including spring force, contact resistance, random, half sinus and sinusoidal vibration, rapid temperature change, dry heat, cyclic damp heat, cold test and current carrying capacity.

These tests are extensive and are performed on 'virgin' parts as well as parts that have been pre-cycled, ensuring that the connectors will give long-term reliability in real-world applications.

Some manufacturers use IEC 60512 as a baseline but add specific additional tests to reflect known applications or address other potential weaknesses as technology changes.

Examples of non-standard tests include an orbital motion test in the X-Y axes. This test specifically targets SLCs to verify that there is a continuous connection between the plunger and the sleeve both directly and through the spring, as a backup. The 'wiggling' X-Y motion attempts to misalign the plunger radially, for a period in excess of three minutes, so that a momentary gap is created between the plunger and the sleeve.

For testing vertical motion in the Z-axis, another non-standard test has been developed specifically for SLCs. The purpose behind this test is to verify the continuity between the plunger and the contact pad as well as checking the free motion of the plunger within the shell. The amplitude of the motion is full stroke and the frequency is swept up to 125 kHz to detect any stickiness of the plunger.

SLCs often connect high-speed digital signals where a loss of connection can be significant. For this reason, any loss of connectivity that lasts longer than 1 µs or generates a voltage spike greater than 1.15V (with .5 amps applied) is deemed to be a failure for either of these non-standard tests.

When specifying SLCs, designers should review all available test data. Reputable manufacturers will often introduce non-standard tests that are specific to certain types of connectors that will provide designers with further assurances about a connector's ability to perform reliably in a certain application.

Also valuable to designers and often a criterion for selecting one brand of SLC over another is the easy availability of design support materials. Most manufacturers will have multiple tools available including detailed 3D models (IGES or STEP) for rapid mock-up of designs and PCB layout recommendations to ensure that the correct land patterns are implemented for optimum SLC operation.

Typical Applications of SLCs

The applications for SLCs are really only limited by the imagination of the designers that specify them. As innovation generates new product categories, there are a number of new applications where these versatile connectors are playing a significant role in enabling future technologies.

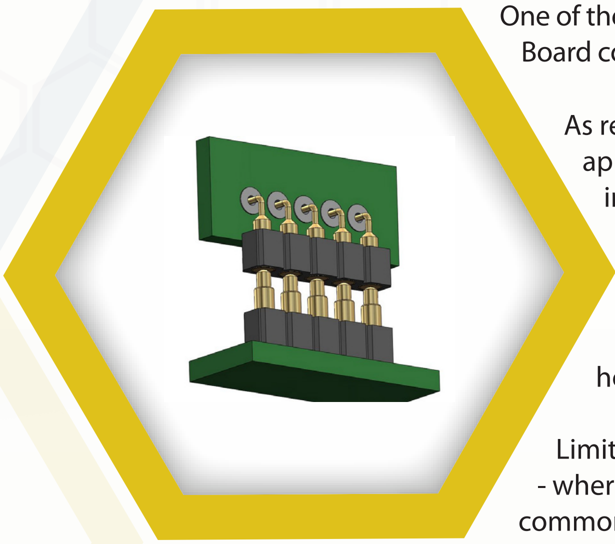

***Figure 9:** Typical right-angle board-to-board SLC solution*

One of the original SLC applications and still by far the most popular is Board-to-Board connectivity between two or more PCBs.

As reducing product size drives space to a premium and modular approaches to design become more popular, manufacturers are increasing the number of PCBs in a product. SLCs allow for multiple boards to be stacked easily, with the SLCs accommodating tolerance stack-ups including small misalignments due to non-parallel fixing or PCB warpage. The versatility of SLCs makes them a viable solution whether the boards are parallel or perpendicular, vertical or horizontal.

Limited space in today's designs is also making so-called 'blind mating' - where one half of the connector cannot be seen during mating - more common. Pin-to-receptacle misalignment during engagement can lead to broken or bent pins, damaged contacts and poor or missing connections.

An SLC is an ideal solution as there is no insertion required. The connection is made with the plunger tip contacting a conductive surface - typically a pad on a PCB or the face of a target pin. These mating surfaces are usually larger than the spring pin plunger, thereby eliminating concerns about alignment and potential damage to components.

As more devices become portable, they rely on battery power and require charging at least once per day - often in a charging cradle. SLCs are a perfect solution for charging batteries in portable instruments as well as docking handheld devices for data and power transfer purposes. They can be easily integrated into any system with numerous options available in terms of height, travel and spring force. Contact is made with the plunger tip and the spring pin allows for blind mating and some misalignment when placing the battery or device in the cradle. This makes it a good choice for this type of application where the end user makes the connection.

SLCs with solder cup or wire crimp termination features can be used in wire or cable harness applications. Terminating the cable into an SLC and over-molding or press-fitting SLCs into a plastic housing allows the creation of a cable terminated connector with the advantages of a spring-loaded contact as the connection point.

Once again, this is excellent for blind mating and quick connect applications typically associated with cable connectors. The superior performance of SLCs under shock and vibration conditions provides sustained reliability in the long run, making them a good fit for the constant handling and jostling of cables.

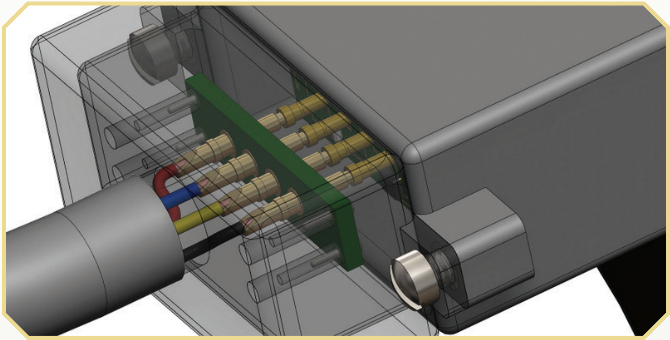

***Figure 10:** SLCs are ideal for creating blind-mate solutions that eliminate the possibility of contact damage*

However, SLCs are not only used in end products. Many test departments rely on them for 'bed of nails' automated functional testers where they provide an easily accessible means of quickly mounting and de-mounting the board to be tested, with high tolerance and reliability.

Technology Examples

One of the companies at the forefront of standard and custom SLC solutions is Mill-Max Mfg. Corp. Its comprehensive range of standard SLCs comprises over 70 different product families covering just about every conceivable configuration, as well as a total of 45 different target connectors (and 28 loose pin target products) for use in conjunction with the wide range of SLCs.

The range includes single and double row headers suitable for through-hole, surface mount and wire termination. Connectors are available on .100", .050" and 2mm grids with various force, stroke and initial height options. Bulk and tape-and-reel packaging are offered to suit a wide variety of production processes.

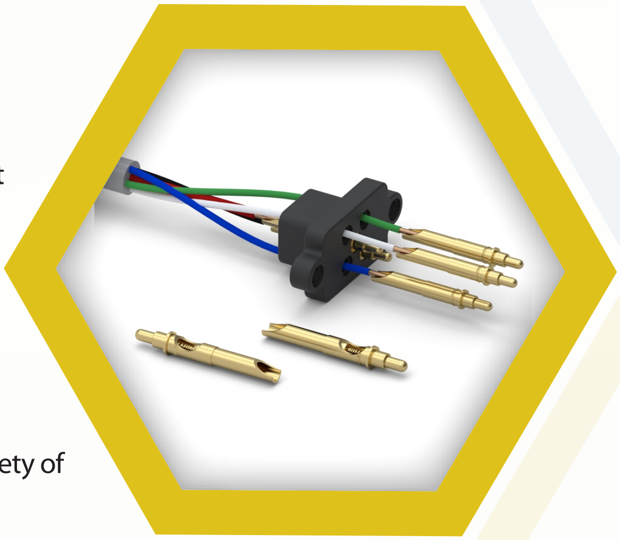

Figure 11: *SLCs can be used for innovative and highly reliable cable assemblies*

The Mill-Max range comprises nine product families targeting rugged applications. These brass alloy devices feature 20 micro-inches of gold plating over nickel giving durable performance up to one million cycles.

Figure 12: *The larger series of power spring pins shown alongside standard series contacts*

Specifically designed for rugged applications, these devices have extended bearing surfaces and ample body wall thickness as well as solid plungers and stainless steel springs.

The high force spring gives a force of 120 grams at mid-stroke and allows for strokes up to 0.090" (2,286 mm). They excel in rugged environments, operating from -55°C to 125°C and guarantee no electrical discontinuity greater than 1µs nor any voltage spikes in excess of 1.15V (with .5 Amps applied) for shock up to 50 G or 200 Hz vibration up to 10 G.

The low contact resistance of 20 mΩ (max.) allows for currents up to 9 Amps to be handled, with temperature rises below 10°C.

While the vast array of solutions to be found on the Mill-Max website may appear bewildering, designers are easily able to narrow down the options with multiple search options including product type drill-down, picture-based searching and part number-based search using either Mill-Max or competitor part numbers.

About Stephen Capitelli

Stephen has a BSEE from Pratt Institute and is currently the Manager of Product Engineering at Mill-Max Mfg. Corp. He has more than 20 years of experience in the electronics industry designing connectors for PC board applications. He has worked with countless suppliers helping them to source the exact connector for their interconnect requirements.

About Mill-Max Manufacturing

Founded in 1971, Mill-Max Mfg. Corp. is the leading U.S. manufacturer of machined interconnect components with a vertically integrated manufacturing facility headquartered at 190 Pine Hollow Rd., Oyster Bay, NY 11771. Its full product line includes spring-loaded connectors, SIP, DIP, PGA and BGA sockets, board-to-board interconnects and pin headers, surface mount and custom products, PCB pins and receptacles, solder terminals, wrapost receptacles and terminals. The company's complete manufacturing facility includes engineering, tooling, primary and secondary machining, stamping, plating, injection molding, and assembly.