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SPRING PROBE CONTACT SOLUTIONS FOR SOLDERLESS INTERCONNECTIONS

Engineering Superior Solutions

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HYPERTAC INTERCONNECT DEVICES SABRITEC

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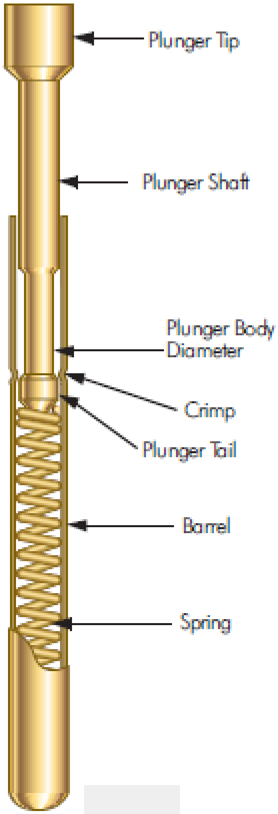
Basic Questions

What are spring probes?

- **In the simplest form a spring probe is a pair of telescoping cylinders fitting together with a spring in between to push them apart**
- **They are typically used to interconnect parallel PCB's**
- **Spring probes are in many electronic systems including space, cell phones, military electronics, aerospace electronics, medical devices and in most high density test areas**
- **Support low and medium power DC to high frequency digital and RF signals in either single ended or differential formats**
- **Spring probes found in low and high density packages with center to center probe pitch dimensions to below 0.5 mm (robustness is proportional to pitch and spring probe size)**
- **Spring probes can tolerate temperature ranges from benign to extreme (-65ºC to +260ºC) based on the materials used**
- **Spring probes have demonstrated performance in very demanding mechanical shock and vibration environments**
  - Mechanical Shock – accelerations > 5,000 g's and Vibration > 120 g's random RMS (dependent on spring force and material selection)



Typical Probe

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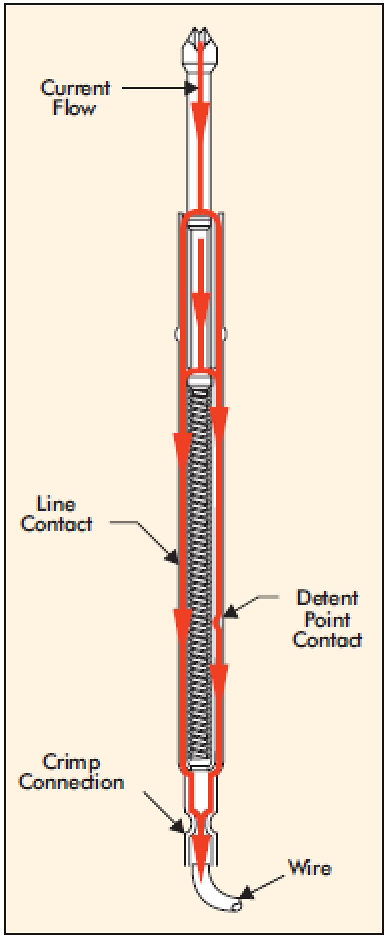
Basic Questions - continued

- **Why do you need them in space applications?**
  - Space applications / performance
    - **Minimum packaging space and weight** to replace parallel PCB connectors
    - **Flexibility/ adaptability** - various electronic packaging configurations addressing both electronic and thermal concerns
    - **Modularity** supporting basic architecture, while allowing for upgrade and expansion for evolution of a family of satellites or space equipment
    - **High reliability** - extreme temperature, mechanical shock and vibration environments
    - **Stable connection** resistance performance and high speed / RF signal integrity in the extreme environments
    - **Low or zero out-gassing** of materials
    - **Low or zero radiation susceptibility** / degradation
    - **Proven solderless connections** to eliminate solder and plated through holes (stub elimination / reduced capacitance for improved high speed performance)



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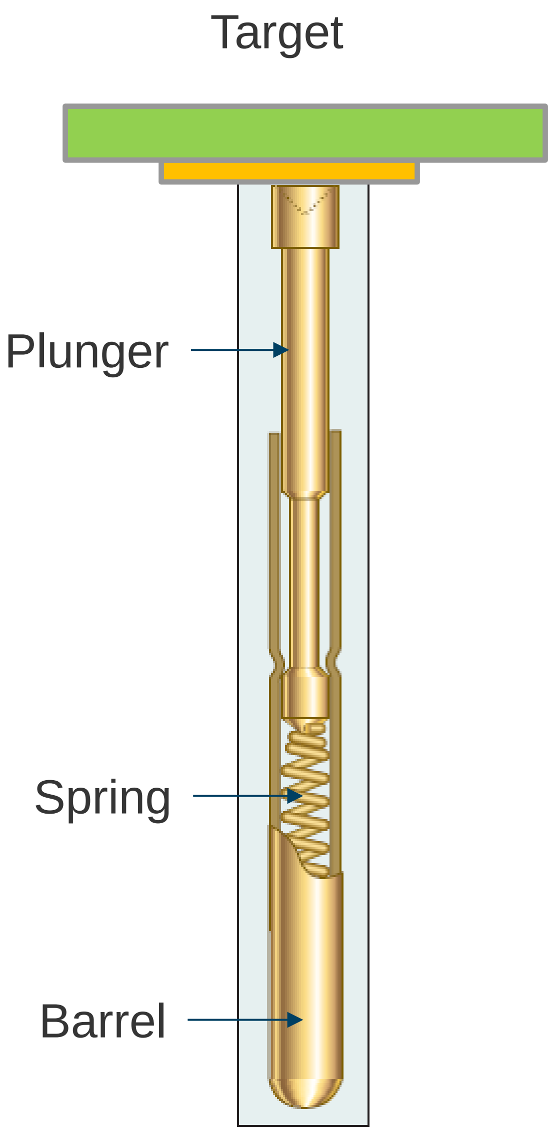
Spring Probe Contact and Connector

- Typical Spring Probe consists of a plunger, spring and barrel
- Plunger – one or more moving contact members to interact between the body of the probe and the target (mating contact)
- Spring – primary force driving the plunger out of the barrel towards the mating target
- Barrel – cylindrical outer body of the spring probe contact
- Target – conductive pad on a PCB or contact in a mating connector



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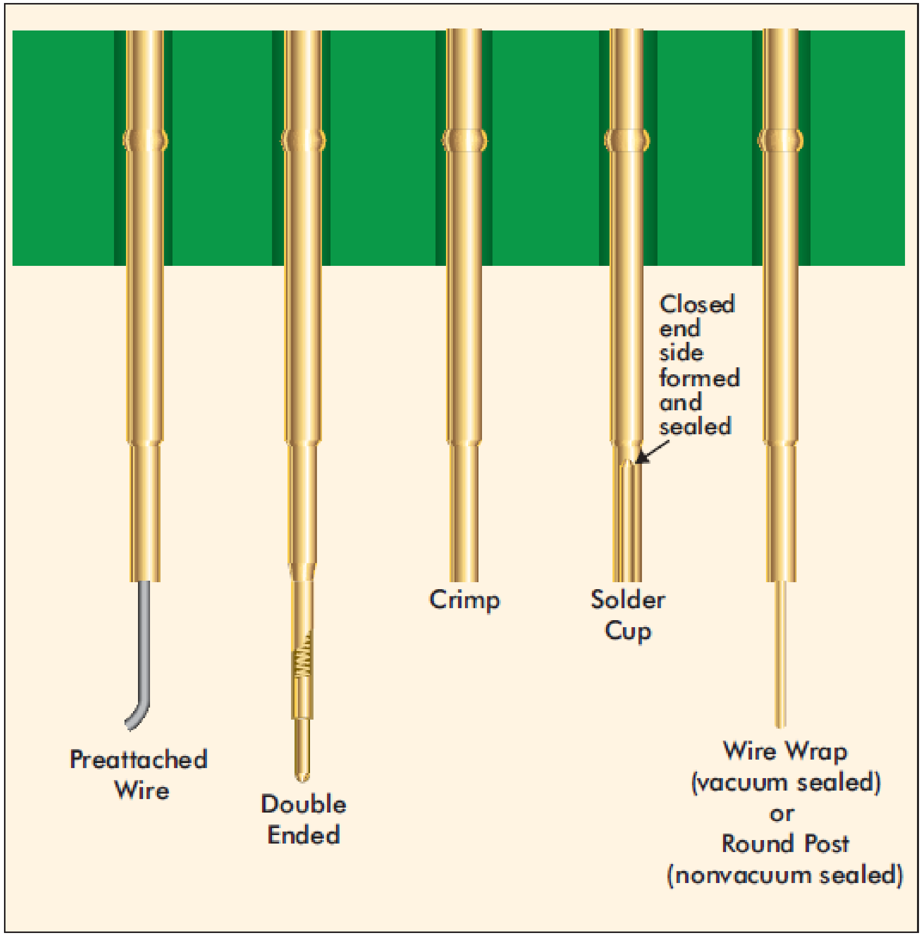
Spring Probe Design Basics - Termination

Receptacle Spring Probe Termination Styles

- Spring Probe Designs are developed with a number of termination options
- Pre-attached wires allow for pigtails
- Double Ended allows for the spring probe to be sandwiched between parallel PCB's or Targets
- Crimp or Solder Cup provide for field or downstream wire termination
- Wire Wrap or through hole solder tail provide for older termination methods to solid wires or PCB's
- **Surface Mounted soldering or Double Ended probes are most popular in Mezzanine parallel board applications**



Surface Mount – Soldered Spring Probe

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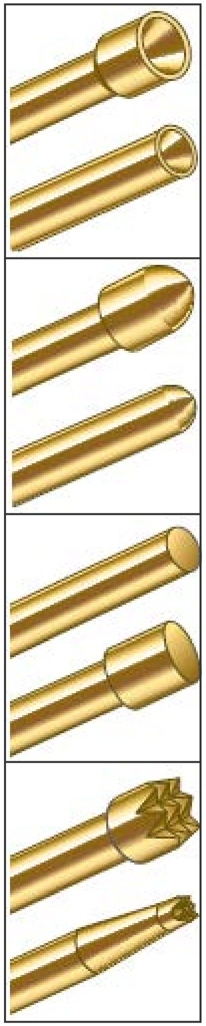
Spring Probe Design Basics – Plunger Tips

8 Basic Spring Probe Plunger Tip Geometries

1. **Concave Tips – A or G**
   - Used to support 3-D targets to ensure nesting in the cup
   - Not recommended for dirty applications and aggressive contacts
2. **Spherical Radius Tips – D or J**
   - Produces minimum indentation on the target contact
   - Best for high mate and unmate cycles
   - Effective in addressing dirty applications
3. **Flat Tips – C or F**
   - Used to maximize probe to target contact area
   - Easily disrupted by dirt and angular mismatch between probe and target
4. **Serrated Tips – H or HT**
   - Best for electrical performance with mildly aggressive contact, multi parallel contact paths, and dirty surfaces
   - Used with flat or 3-D targets
   - Can be more expensive



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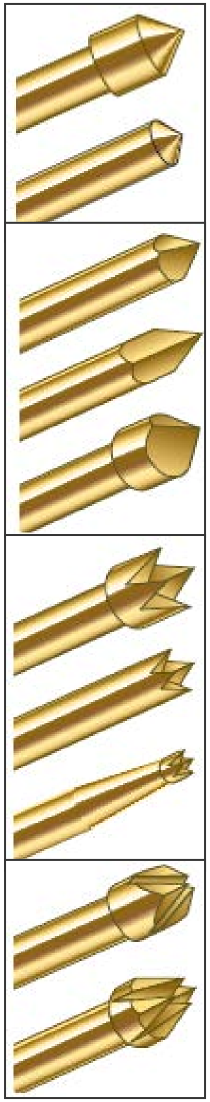
Spring Probe Design Basics – Plunger Tips (continued)

8 Basic Spring Probe Plunger Tip Geometries

5. **Conical Tips – E or B9**
   - Conical tips are used to contact metallized targets such as plated through holes or vias on PCB's
6. **Chisel Tips – S, SW or T**
   - Chisel tips are similar to the conical tips. They are conical tips with faceted sides providing knife-like edges to cut into the surface
7. **4-Point Crown Tips – W, U or UST**
   - Multi-point crown tips are used in applications like those of the serrated tips. The multi-point tips are typically cut deep to provide a "self cleaning" action.
8. **Multi-Point Tips – TX or X**
   - This tip attempts to combine both the chisel's focused contact on female targets and the multi-point's effectiveness with convex targets.



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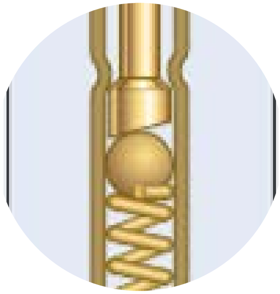
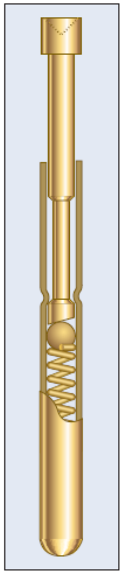
Biasing Methods

- **Spring probe designers have been looking for the perfect balance between contact resistance stability, force, and debris displacement through "wipe"**
- **Most modern probes incorporate "biasing" or forcing a tilt into the plunger resulting in micro-wipe on the target and increased force between the plunger and the inside of the barrel**
- **Primary biasing methods include:**

Bias Ball

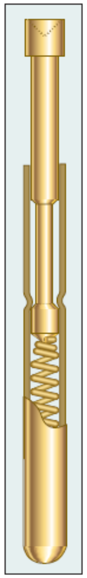
- Oldest and most aggressive method
- Reduced durability and increased length
- Best electrical performance





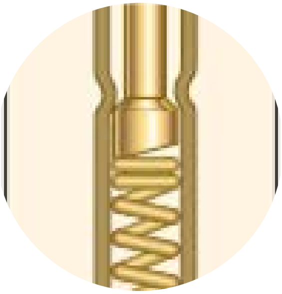
Bias Spring

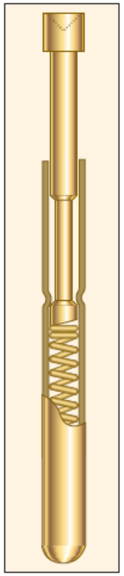
- Wedge shaped plunger meets tapered spring to cause bias
- Bias is more random distributing wear
- Poorest electrical performance



Bias Plunger

- Improved spring manufacturing permits the ball removal
- Reduced durability, but less aggressive
- Strong electrical performance





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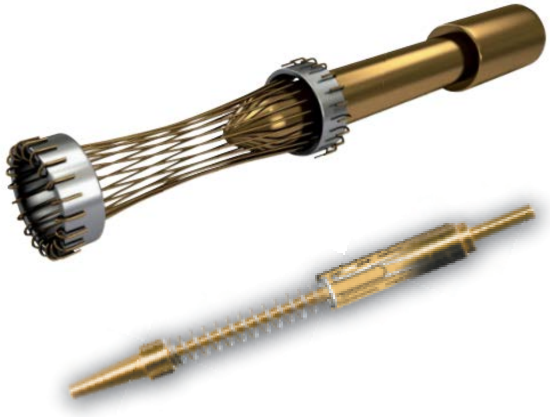
Alternative Spring Probe Designs

- **Hyperspring**
  - A marriage of the highly reliable hyperboloid contact and a spring loaded plunger to provide high durability, high shock and vibration performance and very stable contact resistance
  - Primary negatives are cost and length



- **Bifurcated**
  - Provides additional contact using bifurcated beams at the front of the barrel to the plunger
  - Beam geometry typically generates a stiff beam and significantly increased wear
  - A more forgiving beam length results in a major increase in length of the probe

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Materials for Spring Probe Design

Spring Materials

- **Typical materials includes:**
  - **Beryllium Copper**
  - Stainless Steel
  - Carbon Steel

	Operating Temp (°C) 1 Hour	Percent Load Loss <u>Preload Condition</u> Rated Compression	Operating Temp (°C) 24 Hour	Percent Load Loss <u>Preload Condition</u> Rated Compression
BeCu Ø .005"	205	14.5	120	13.6
		64.4		59.9
S.S. Ø .004"	260	2.8	180	3.1
		12.4		13.4
Music Wire Ø .007"	120	0	85	0
		1.8		3.7

Plating

- **Typical plating includes:**
  - **Gold over Nickel**
  - Nickel
  - Duralloy
  - Palladium Nickel
  - Pure Palladium with a Gold Flash

Comparison of Plunger Plating Characteristics

	Gold	Nickel	Duralloy™
Resistivity (Ω cir mil ft)	11.4-28.9	181.5-331.0	64-90
Hardness (Knoop)	160-190	500-600	930-1100
Hardness (Rockwell B)	78-86	—	—
(Rockwell C)	—	47-53	>68
Tensile Strength (ksi)	16-31	100-122	101-112

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Materials for Spring Probe Design - continued

Barrels

- The majority of barrels are **nickel silver** driven by the high strength, ductility and manufacturability (machined or deep-drawn)
- Other materials include beryllium copper or brass for machined barrels
- Phosphor bronze or brass are alternatives for a deep-drawn barrel

Barrel Materials

	Nickel/Silver	Gold Plated
Resistivity (Ω cir mil ft)	186.5	11.4-28.9
Hardness (Rockwell B)	40-55	78-86
Tensile Strength (ksi)	65	16-31
Yield Strength	25-27	—

Plungers

- **Beryllium Copper** is predominantly used for the base material on plungers to support the conductivity, strength and wear characteristics needed
- Tool steel and stainless steel had also been used, but machining becomes harder with decreased diameters
- Steel does provide improved wear performance, but at greater cost, higher resistance and is magnetic

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Connector Development Considerations

- **“Hard stop”** features must be included in the connector to prevent over compression of the contact (i.e. plunger going beyond its maximum travel)
- **Fastening features** are recommended to minimize the relative movement of the plungers and targets (usually gold pads on the PCBs), especially for high shock and vibration (typically failure mode results from the plunger sliding of the target, not plunger bounce in the Z axis)
- **Maximize pad dimensions** in the target hardware to avoid or minimizing slippage or alignment problems
- **Guiding screws / features / dowel pins** should be included to ease the assembly and reduce relative movement along the X/Y plane (if the design will not support guide features, tolerance stack analysis become critical)

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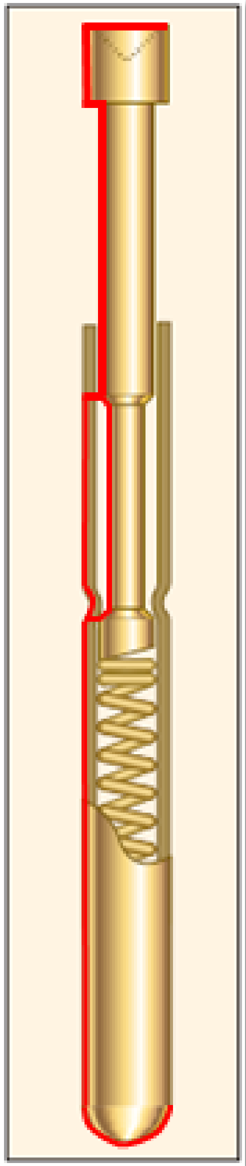
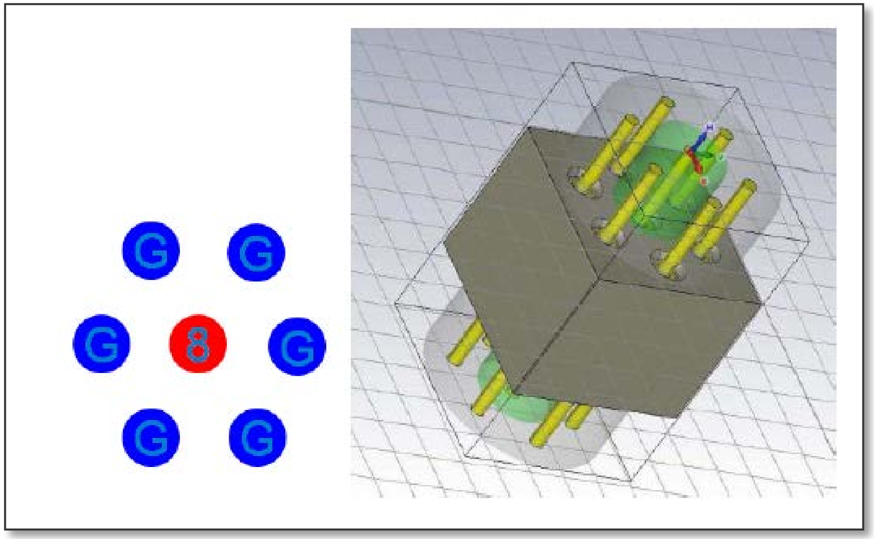
High Speed / RF / Coaxial

- A consistent diameter of the spring probe for a uniform impedance along the contact
- The biased probe design ensures that the signal is conducted on the skin of the barrel and not through the spring (Signal in RED)
- Grounding and shielding is provided through a number of design approaches with the simplest consisting of a signal surrounded by a pin field (or palisade) of discrete ground pins



- Insertion Loss
  - ~ 0.5 dB at 25 GHz



- Effective for MHz speed signals or with limited shielding requirements (GHz) and works for both single ended and differential connections

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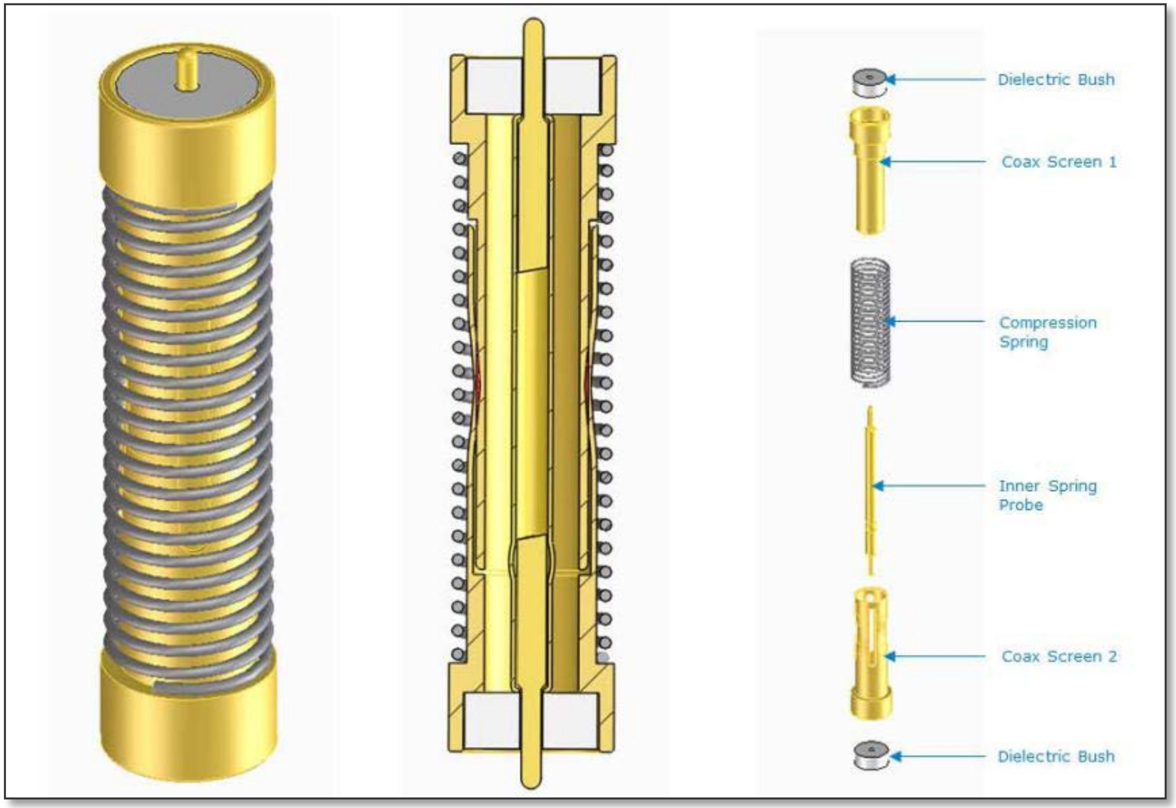
High Speed / RF / Coaxial

- There are also true coaxial spring probe configurations with either semi-rigid and variable length 360º ground shields
- The primary negative is the increase in complexity



- Return Loss <-20dB
- Insertion Loss <0.1dB
- Total spring Force 3N Max
- Impedance 50 ohm
- Frequency range 12GHz
- RF Power 20% duty ratio: 3W
- Shielding > 80 dB

Variable Length Coaxial Spring Probe

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Other Benefits of Spring Probe Connections

Elimination of Solder Tails

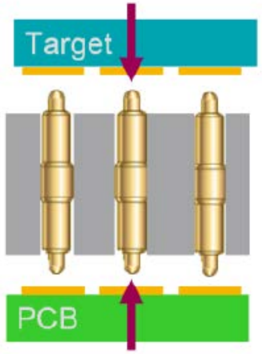
- Elimination of soldering supports environmental compliance - Lead free – tin whiskering – deadly for space
- Removal of contact "stubs" or tails also allows for blind vias in the PCB rather than plated through holes, thus reducing the capacitance caused by the plated through holes with lower impact on system impedance

Thermal Packaging

- The parallel PCB connection and flexibility of probe placement allows for many different thermal management techniques
- Area for heat sinks, heat pipes, liquid cooling or radiative heat dissipation can be planned using probes

Blind Mate Connection

- Low profile parallel PCB interconnect provides for a compact package
- X and Y axis compliance can be increased through adjustment of target pad size
- Z axis compliance can be adjusted using plunger travel



Rapid Adaptability

- Spring probes eliminate the need to use heavy cables or long conduction paths through backplanes
- The piggy backing of a parallel PCB allows for stacking while minimizing connection path and space requirements

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Why do you need them in space applications?

- **Proven technology for space applications**
- **The ability to optimize:**
  - The packaging volume
  - Signal integrity performance without dramatic weight increase
  - Thermal management flexibility
  - Blind Mate adaptability
- **Extreme environment performance**
  - Extreme mechanical shock and vibration performance (>5,000g's and 120g's Random Vibration – spring force and design dependent)
  - Capable of temperatures from -60ºC to 150ºC (BeCu spring) / 260ºC (Spring steel)
- **Recommended Design for Space**
  - Spring probe design best suited for space is the biased plunger
  - Double or Single ended spring probes are ideal for parallel PCB stacking depending on the needed amount of Z axis travel and packaging space available
  - Plating – gold over nickel
  - Spring Material – BeCu for most applications / Stainless Steel or Spring Steel for extreme acceleration levels
  - Plunger material – BeCu / Barrel material – Nickel Silver or BeCu
  - Plunger and barrel tip geometry – a spherical tip geometry gives the best compromise of aggressiveness on the target and reduced wear in micro motions or durability

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