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Interconnect Sockets and Applications

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Yoinjun Shi – Twinsolution Technology
 Agenda

1. Introduction and Background
   – Second-Level-Interconnect definition
   – Purpose of interconnect sockets
   – Benefits of sockets

2. Contact Element
   – Single-compression Vs Dual-compression
   – Contact resistance theory
   – Examples of calculating resistances
   – Relationship between contact load, contact travel and contact resistance
3. Types of Contacts
   - Polymer-based
     - Metallized and wire-type
   - Particle Interconnect
   - Metal-based
     - Spring-loaded
     - Stamped-and-formed
     - Particle and Wire-type
     - Screw-machine
     - MEMS–based
     - Buckling
   - Summary
Agenda

4. Contact Element Material
   – Contact material requirement
   – Types of material and plating
   – Contact material selection

5. Printed-Circuit-Board and Hardware Requirements
   – Surface finish requirement
   – Mechanical tolerances (positional and absolute)
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   - Cross-talk
   - Current carrying capacity (CCC)
   - Impedance (capacitance and inductance)

7. Interconnect Socket and System Design
   - Types of interconnect system
   - Mechanical hardware design and tolerances
   - Force-deflection analysis
Agenda

8. Socket Interconnect System Testing
   – Daisy-chain packages and CRES test board
   – Electrical - Test fixture example
   – System qualification -- Environmental test

9. Real-world Examples and Summary of Technologies

10. Design Process Flow and Check-list

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Section 1
Introduction and Background
Interconnect Socket Definition

- An electrically conductive interface element placed between an electronic component and a printed-circuit-board to make reliable interconnection between the device and PCB.

Examples of Interconnect Sockets

Interconnect Socket Schematic

- Electronic Component/Device (e.g. BGA)
- Conductive Element (Socket)
- Printed Circuit Board (PCB)
What is Second-Level-Interconnect (SLI)

- Package Substrate
- First-Level Interconnect
- Silicon Die
- Solder Balls (Pb-free)
- Second-Level Interconnect
- Printed-Circuit-Board
What is Second-Level-Interconnect (SLI)

- Package substrate
- Package to socket to PCB interconnect system
- PCB fab
Interconnect System

- Interconnect system solution
  - The Interconnect System is comprised of a conductive socket element and a mechanical hardware system
  - The design of the mechanical hardware is dependent on the type of socket and mechanical properties of the socket

Interconnect Sockets and Applications
Types and Benefits of Sockets

- **Test and Burn-in sockets**
  - Testing multiple devices using the same socket attached to the same PCB -- cannot be done if the device is soldered
  - Test sockets -- Typically ordered in low volume quantities and require short insertion times
  - Burn-in sockets – Typically ordered in high volume quantities and require high insertion times

- **Validation sockets**
  - Used during the first power-on of the new silicon
  - Validation of multiple packaged silicon devices using the same socket attached to same PCB – cannot be done if the device is soldered
Types and Benefits of Sockets

- **Validation sockets (Cont’d.)**
  - Same socket used during subsequent silicon stepping changes
  - These sockets are typically ordered in medium volume and requires medium number of insertion/removal cycles

- **Production sockets for final products**
  - Allows PCBs assembled ahead of the first silicon arrival – sockets are typically soldered to PCB
  - Require low number of insertion/removal cycles but are ordered in high volume quantity
  - Low cost/unit
  - High tooling cost
Examples of Different Types of Sockets

- **Test & Burn-in sockets**
  - Test: Typically uses machined pogo pins
  - Burn-In: Typically uses stamped-and-formed pins

- **Validation sockets**
  - Typically uses elastomeric contact or stamped spring pins

- **Production sockets**
  - Typically uses stamped-and-formed pins
## Comparison of Requirements on Test and Burn-in Sockets

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Test socket</th>
<th>Burn-in socket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertions</td>
<td>100K to 1Million</td>
<td>10,000 Typical</td>
</tr>
<tr>
<td>Electrical</td>
<td>High frequency</td>
<td>Low frequency</td>
</tr>
<tr>
<td></td>
<td>Low inductance (&lt;3nH)</td>
<td>High inductance (5 to 13nH)</td>
</tr>
<tr>
<td>Production method (housing)</td>
<td>Machined</td>
<td>Injection Mold</td>
</tr>
<tr>
<td>Contact technology</td>
<td>Pogo, Particle Interconnect, Fuzz button</td>
<td>Stamped and formed BeCu spring contact</td>
</tr>
<tr>
<td>Device insertion times</td>
<td>3 seconds to 5 minutes</td>
<td>8 hours to 1,000 hours</td>
</tr>
<tr>
<td>DUT board type</td>
<td>Surface-mount</td>
<td>Through-hole</td>
</tr>
<tr>
<td>Typical order size</td>
<td>1 to 100 Sockets</td>
<td>300 to 20K sockets</td>
</tr>
<tr>
<td>Typical cost (Each)</td>
<td>$1,000-$6,000</td>
<td>$4-$200</td>
</tr>
<tr>
<td>Market Size</td>
<td>$80M-$100M</td>
<td>$250M-$300M</td>
</tr>
</tbody>
</table>
Section 2
Contact Element Fundamentals
Single-compression Socket

Definition:
Socket is defined as a single-compression socket when the contact element is soldered to the surface of one device (typically of a PCB) and compressed at the other end where it interfaces with the second device (typically a BGA component).
**Definition:**
Socket is defined as a dual-compression socket when the contact element is compressed between the two surfaces to make electrical connection. These surfaces are typically BGA device at one end and PCB at other end.
Contact Resistance Theory

- Contact resistance occurs between
  - Interconnect pin surface and PCB pad surface
  - Interconnect pin surface and solder ball surface

- Higher contact resistance results in thermal and electrical losses

- Practical surfaces have surface roughness due to manufacturing operations

- Practical Contact Area << Design Contact Area

![Diagram showing contact resistance theory with surfaces and forces]
Contact Resistance Theory (Cont’d.)

- Thin film forms on metal surfaces (Cu, W, Ag, SAC 305 etc) due to oxidation
- Interconnect pin wiping action is used to break oxide film lowering contact resistance
- Interconnect pin punctures into oxide film lowering contact resistance for vertical interconnect pins
Contact Resistance Theory (Cont’d.)

- Total Contact Resistance = \( R_{i\text{-ball}} + R_i + R_{i\text{-pad}} \)
  - \( R_{i\text{-ball}} \): Contact resistance between interconnect contact pin and solder ball
  - \( R_i \): Bulk resistance of interconnect contact pin
  - \( R_{i\text{-pad}} \): Contact resistance between interconnect contact pin and PCB pad
Contact Resistance Theory: Bulk Resistance

- **Bulk Resistance** \( R_i = \frac{\rho L}{A} \)
  - \( \rho \): Resistivity of the interconnect material (\( \Omega \)-m)
  - \( L \): Length of the interconnect (m)
  - \( A \): Cross-sectional area of interconnect (m\(^2\))

Assumption:
- Length of interconnect = 6 mm
- Diameter of interconnect = 0.25 mm

<table>
<thead>
<tr>
<th>Material</th>
<th>Resistivity(( \Omega )-m) at 20(^\circ)C</th>
<th>Bulk Resistance (m(\Omega)) at 20(^\circ)C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>1.68x10(^{-8})</td>
<td>2.05</td>
</tr>
<tr>
<td>Silver</td>
<td>1.59x10(^{-8})</td>
<td>1.94</td>
</tr>
<tr>
<td>Gold</td>
<td>2.44x10(^{-8})</td>
<td>2.98</td>
</tr>
<tr>
<td>Tungsten</td>
<td>5.6x10(^{-8})</td>
<td>6.84</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>69x10(^{-8})</td>
<td>84.34</td>
</tr>
</tbody>
</table>

For Copper pin of length 6mm and diameter of 0.25mm, bulk resistance \( (R_i) \) is very much smaller than the total contact resistance \( (R_{i-ball} + R_{i-pad}) \).
Contact Resistance: Relationship with Force

- Linear or non-linear behavior of Force/Load and Compression relationship
  - Analyzed using Finite Element Analysis (FEA) and experimentally validated
- Total Resistance and Force/Load relationship is experimentally measured

**Free State**

- Total Force $F=0$
- BGA Device
- PCB
- Fixed Boundary

**Compressed State**

- Total Force $F = \text{"X" lbs}$
- BGA Device
- PCB
- Fixed Boundary

Compression $\delta=0$

Compression $\delta$
Force-Deflection of Beam—Fundamentals

Simply Supported Beam
Uniformly Distributed Load

\[ R = \frac{w \ell}{2} \]
Max. deflection (center) = \( \frac{5wl^4}{384EI} \)

\( \ell = \) length of the beam
\( w = \) unit load
\( R = \) Reaction force

\( E = \) Young’s Modulus of beam material
\( I = \) Moment of Inertia of the beam

Beam Fixed at Both Ends
Uniformly Distributed Load

\[ R = \frac{w \ell}{2} \]
Max. deflection (center) = \( \frac{wl^4}{384EI} \)

The maximum deflection of the PCB due to socket load can be approximated using one of the formulae above.

Interconnect Sockets and Applications
Contact Resistance – Relationship with Force and Deflection

Typical Force-Deflection and Resistance-Deflection Curve of Socket Contact

- 25 grams
- 15 grams

Deflection

Typical operating deflection range

.011” .016”

Resistance

100 milli-ohms
75 milli-ohms

Typical operating deflection range

- 25 grams
- 15 grams

Deflection
Contact Element Characterization

- Important to characterize contact element performance prior to building an array/socket
  - Typically performed by building a small coupon with 1-4 contact elements

- Mechanical characterization includes
  - Force Vs Compression at room & at high temperature (>100°C)
  - Maximum force/compression to yield/set
  - Number of cycles to failure (material yielding, tip plating wear, etc)

- Electrical characteristics include
  - Total resistance of contact element at room and at high temperature (>100°C)
  - Current carrying capability at room and at high temperature (>100°C)
Contact Element Characterization: Experimental Setup

- Total resistance is measured using 4-wire setup
  - Removing path resistance
- Setup is used to measure current carrying capability of contact element

4-wire measurement circuit

\[ R_{\text{subject}} = \frac{\text{Voltmeter indication}}{\text{Ammeter indication}} \]
Section 3
Types of Contacts
Polymer-based Contacts

Two types of Contacts:
1. Polymer with conductive metal
2. Polymer with embedded metal spring element

1. Polymer with conductive metal

Description:
-- Polymer (silicone rubber) filled with conductive powder (Ag or Au)

Primary advantages:
• No ball damage
• Dual-compression solderless system
• Socket can be easily replaced if damaged
• Custom and mixed pitch
• Excellent electrical characteristics
• Can be scaled down to <0.4mm
Polymer-based Contacts (Cont’d.)

1. Polymer with conductive metal

**Shin-poly technology**

**Description:**
- A Matrix of vertical wires suspended in a non conductive polymer.
- Suspended in 2 configurations, GB (vertical wires) and MT (angled wires).
- Both with wire pitches as small as .03 mm. (approx. 1mil)

**Primary Advantages:**
- No ball damage
- Socket can be easily replaced if damaged
- Dual-compression solderless system
- Extremely Low Height
- Custom and mixed pitch
- Excellent electrical characteristics
- Can be scaled down to <0.4mm
Polymer-based Contacts (Cont’d.)

1. Polymer with conductive metal INVISIPIN® technology

Description:

- Manufactured by R & D Altanova, Inc
- Solderable, individual conductive elastomer pin
- Pick and place / solder reflow compatible
- Infinitely configurable

Primary advantages:

- No ball damage
- Individual contacts can be easily replaced if damaged
- Dual-compression solderless or soldered system
- Extremely Low Height
- Custom and mixed pitch
- Excellent electrical characteristics
- Can be scaled down to 0.4mm

Courtesy: R&D Altanova, Inc.
Polymer-based Contacts (Cont’d.)

2. Polymer with metal spring element:

Description:
- Continuous wire spring structure supported by elastomer

![6-wire spring 12-wire spring](image)

Courtesy: HCD

Primary advantages:
- Drop in replacement for pogo pins
- Consistent resistance values
- Dual compression solderless system
- Custom and mixed pitch
- Can be scaled down to 0.4mm pitch
- Higher cycle life than metal-filled polymers
Particle Interconnect

Description:
- Uses sharp, metallized, particles which have been screened by size.
- Attached onto contact pads on the surface of conductor using standard masking and electroplating processes.
- The sharp, embedded particles create a conductive "micro bed-of-nails" that makes many parallel electrical paths by penetrating through any oxide without requiring a wiping action as conventional contacts.

Primary advantages:
- Extremely Low Height
- Custom and mixed pitch
- Excellent electrical characteristics
- Can be scaled down to <0.4mm
Description:
- Contacts are manufactured from a long strand of highly specialized very fine wire
- The most common wire materials used are either a Gold-plated Beryllium Copper alloy (Au/BeCu) or a Gold-plated Molybdenum (Au/Mo).
- Au/BeCu offers the lowest signal distortion levels and high mating cycle repeatability
- Au/Mo is utilized because of its high level of structural stability at temperature extreme

Primary advantages:
- Can be scaled down to 0.4mm pitch
- High current carrying capability
- High cycle life
- Excellent electrical characteristics
- Extreme operating range – (-60°C to 150°C)
- Various diameter and length wires available depending on the application
Description:
- Spring-loaded contact (typically known as pogo-pin) is a device used to establish electrical interconnection between two surfaces. These surfaces could be pads of the printed-circuit boards or solder balls of BGA devices.

Primary advantages:
- High cycle life
- Consistent resistance value and reliable interconnection
- Can be scaled down to 0.4 and less
- Can withstand higher temperatures
Spring Pin (stamped)

Description:
- Piece parts are made using stamping process
- Spring probe pins are assembled using automated machine

Primary advantages:
- Short length possible, 0.8mm, good for extremely high speed application
- Small diameter possible, good for finer pitch, 0.15 mm pitch
- Easier for mass production as parts are made by stamping
- High working range, 0.8mm traveling in 3.3 mm length
- Low cost

Courtesy: IWIN Co. Limited
Stamped-and-Formed Contacts

Description:
- Made from reels of flat stock material
- Strips run through stamping and forming die to form socket contacts
- Contacts are electro-plated and inserted into the housing

Primary advantages:
- Low-cost
- High-volume application
- Can be single-compression or dual-compression socket
- Applications include production sockets, crimped contacts, etc.
**Pin and Socket Contacts**

**Description:**
- Contacts are typically made on a screw machine
- Comprised of two parts – Female receptacle and Male header
- Standard contacts can be inserted into a variety of housings to create IO connectors, sockets and board-to-board connectors.

**Primary advantages:**
- Consistent and reliable contact resistance
- Low tooling cost
- Medium cycle life (insertion/removal)
- Application includes validation socket and board to board interconnect

![Diagram of Pin and Socket Contacts](image)

*Courtesy: Advanced Interconnection*
MEMs-based Vertical Interconnect

Description:
- Made from 2D MEMs process
- Contacts are plated
- One end is soldered down
- Tips puncture into silicon (Cu) bump

MEMs basic processes:
- Physical Vapor deposition & chemical deposition
- Electron beam and Ion beam Lithography
- Etching processes – Wet and dry etching

Primary advantages:
- Low force <10gf
- Ultra-fine pitch <150um
- High cycle life
- Application include silicon testing
**Buckling-based Interconnect**

**Description:**
- Manufactured from Flat/round wire spool or 2D MEMs
- Floating pin or one end is soldered
- Contacts are plated
- Tips puncture into silicon (Cu) bump

**Primary advantages:**
- Low force <10gf
- Ultra-fine pitch <200um
- High cycle life
- Application include silicon testing

Courtesy: Buckling Beam Solutions
**Summary**

<table>
<thead>
<tr>
<th>Type of Contact</th>
<th>Primary Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer-based contacts (filled with metal powder)</td>
<td>- Superior electrical characteristics, can be scaled down to &lt;0.4mm pitch</td>
</tr>
<tr>
<td>Polymer-based conductive sheet</td>
<td>- Superior electrical characteristics, can be scaled down to &lt;0.4mm pitch, alignment of sheet to the pads not needed</td>
</tr>
<tr>
<td>Polymer based contacts with metal spring element</td>
<td>- Higher cycle life than metal-filled polymer, consistence resistance value</td>
</tr>
<tr>
<td>Polymer based contacts -- Invisipin®</td>
<td>-- Superior electrical characteristics, can be scaled down to 0.4mm pitch, dual compression or solder mount, individual pin can be replaced</td>
</tr>
<tr>
<td>Particle Interconnect</td>
<td>- Superior electrical characteristics, can be scaled down to &lt;0.4mm pitch,</td>
</tr>
<tr>
<td>Fuzz Buttons®</td>
<td>- Superior electrical characteristics, can be scaled down to 0.4mm pitch, high cycle life, extreme temperature operating range</td>
</tr>
<tr>
<td>Spring pin (machines)</td>
<td>- High cycle life, can scaled down to &lt;0.4mm pitch (up to 0.2mm), consistence resistance</td>
</tr>
<tr>
<td>Spring pin (stamped)</td>
<td>- Low cost, can be scaled down to &lt;0.2mm pitch, high volume production</td>
</tr>
<tr>
<td>Stamped and formed contacts</td>
<td>- Low cost, high-volume application, consistence resistance</td>
</tr>
<tr>
<td>Pin and Socket Contact</td>
<td>- Consistence resistance, low tooling cost</td>
</tr>
<tr>
<td>MEMs-based Vertical Interconnect</td>
<td>- High cycle life, low force, ultra fine pitch &lt;0.15mm</td>
</tr>
<tr>
<td>Buckling-based Interconnect</td>
<td>- High cycle life, low force, ultra fine pitch &lt;0.20mm</td>
</tr>
</tbody>
</table>
Section 4
Contact Element Material
Contact Material Selection Factors

- Material Availability
- Specific Performance
- Manufacturability
- Cost Effectiveness
Socket Contact Selection

Typical Selection Flow

1. Understand Industry Trends
2. Define socket contact requirements
3. Select contact material

Tutorial: Interconnect Sockets and Applications
1. Understand Industry Trends

- Reduction in pitch over time (center to center spacing)
  - Require reduced contact size
  - Require tighter mechanical tolerances

![Graph showing decrease in solder ball pitch over time](image)
1. Understand Industry Trends (Cont’d.)

- Lower normal force
  - Minimize deflection of the socket substrate, package, mechanical hardware and PCB
  - Meet reliability requirements

- Growing number of pins/socket
  - Exceeding 100 contacts/inch and exceeding 3,000 contacts/socket
1. Understand Industry Trends (Cont’d.)

- Single or Dual-compression mount
  - Reliable solder joint (for single compression mount)
  - Provide repeated insertion removal cycles without taking a set

- Higher operating temperatures
  - Infotainment systems > 130ºC

- Shorter development and manufacturing lead time
  - Faster to design and faster to manufacture

- Price
  - Lower product cost
2. Define Socket Contact Requirements

2a. Mechanical
2b. Electrical
2c. Material
2d. Attachment Process
2e. Environment
2a. Mechanical Requirements

- Mating surface material and contact area
  - PCB mating surface, device (BGA) mating surface
- Contact normal force
  - Contact geometry
  - Insertion/extraction force

![Diagram of mechanical requirements with forces and contact areas](image-url)
2b. Electrical Requirements

- **Total socket resistance**
  - Contact resistance (socket contact to ball + socket contact to PCB mating surface)
  - Bulk resistance

- **Current Carrying Capacity (CCC)**
  - Maximum current allowed for a given temperature rise
  - Higher conductivity materials allow greater current flow with less temperature rise
  - Current carrying capacity depends on contact geometry, contact material and normal force
2b. Electrical Requirements (Cont’d.)

- Signal properties
  - Signal to ground ratio -- ratio determines connector noise
  - Capacitance – energy stored in an electrical field between two charged objects – coupling between two conductors
  - Impedance -- The ratio of voltage to current (AC) of an electrical signal propagating through a circuit component.
2b. Electrical Requirements (Cont’d.)

- Signal properties
  - Inductance -- Energy stored in a magnetic field generated by the current looping through an electrical circuit.
  
  - Propagation delay -- The signal delay caused by the connector capacitance. Reduced contactor length reduces the propagation delay
  
  - Cross-talk -- Signals from one line leaking into another conductor because of capacitance or inductive coupling or both – mostly capacitance between two contactors
2c. Material Requirement

- Primary required properties
  - Low contact and bulk electrical resistance
  - Corrosion resistance
  - Low frictional forces – reduces wear and increases cycle life
  - Good spring properties
  - Lower cost

- Typical base contact material
  - Metal – Copper alloys
  - Elastomer – Silicon rubber
2c. Material Requirement (Cont’d.)

- Base material requirement
  - Yield strength. Determines beam deflection allowed within elastic range
  - Conductivity – minimized bulk resistance
  - Hardness – reduces wear and increases cycle life

- Contact interface plating materials
  - Gold (Au)
    - Hard gold or soft gold over Nickel under-plating. Hardness is per knoop hardness – electrolytic gold – 30 to 40 micro-inches
    - ENIG – Immersion gold over Nickel – 3 to 10 micro-inches of gold
2c. Material Requirement (Cont’d.)

- Contact interface plating materials
  - Palladium (Pd) and alloys
    - Usually over-plated with thin soft gold (approx. 10 micro-inches)
    - Pd and its alloys have higher hardness and durability than gold (Au)
  - Tin (Sn) and its alloys
    - Thickness ranges depending on the process
      - Hot dipping
      - Electro plating
2c. Material Requirement (Cont’d.)

- Contact interface plating materials
  - Silver Ag
    - Typically used on the elastomeric contacts – silicon rubber as base material
  - Nickel (Ni)
    - Common material for under-plating
    - Typical thickness 150 to 200 micro-inches

- Types of plating processes
  - Electrolytic plating
  - Electroless plating
  - Hot dipping
2c. Material Requirement (Cont’d.)

- Housing material
  - Typically thermoplastics (polymer-based) is used to support contacts
    - Provide environmental protection
  - Critical property requirement of housing include:
    - Withstand soldering temperatures with low acceptable warpage (Pb-free process)
    - Dimensional stability
    - Moisture resistance
2d. Contact Attachment Process

1. Soldering to PCB, mechanically attaching to device

![Diagram of Soldered-down Socket]

- Motherboard
- Top clamping plate
- BGA Device Single-compression Socket
- Bottom Plate

**Soldered-down Socket**

2. Mechanically attaching to PCB and device

![Diagram of Dual-compression Socket]

- Top clamping plate
- BGA Device
- BGA Dual-Compression Socket
- Bottom Plate

**Dual-compression Socket**
2d. Contact Attachment Process (Cont’d.)

1. Soldering to PCB, mechanically attaching to device
   • Solder process
     - Convection reflow
     - Vapor-phase reflow
     - Manual soldering
     - Wave soldering

   • Mechanical attaching to device
     - Requires custom hardware to make connectivity through compression
2. Mechanical attachment to PCB

- Solderless contacts. Compression mount on both PCB and device end
- Require custom hardware to make connectivity to PCB and device through compression
- Require higher force to make electrical connection than soldering one end and mechanically attaching other

Courtesy: Ironwood Electronics

Mechanical Hardware

Dual Compression, solderless socket
2e. Contact Environmental Requirements

- Common applications include:
  - Consumer
  - Automotive
  - Aircraft
  - Military
  - Computer
  - Telecommunication
## 2e. Contact Environmental Requirements (Cont’d.)

<table>
<thead>
<tr>
<th>Category</th>
<th>Minimum °C</th>
<th>Maximum °C</th>
<th>Approx. Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer</td>
<td>0</td>
<td>+100</td>
<td>~3</td>
</tr>
<tr>
<td>Computer</td>
<td>0</td>
<td>+100</td>
<td>~5</td>
</tr>
<tr>
<td>Automotive</td>
<td>-50</td>
<td>+100 to +150</td>
<td>~10</td>
</tr>
<tr>
<td>Aircraft</td>
<td>-50</td>
<td>+125</td>
<td>~20</td>
</tr>
<tr>
<td>Military</td>
<td>-50</td>
<td>+125</td>
<td>~10</td>
</tr>
<tr>
<td>Telecommunication</td>
<td>-40</td>
<td>+100</td>
<td>~15</td>
</tr>
</tbody>
</table>

**Typical operating temperature conditions** — Can vary depending on application

**Typical life** — Can vary depending on application

### Types of Tests:
- Temperature and humidity
- Gaseous
- Vibration
- Shock
3. Contact Material Selection

- Contact material plays a significant role in design optimization

<table>
<thead>
<tr>
<th>Primary Requirements</th>
<th>Contact Material Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle life/Durability</td>
<td>Contact finish, Resistance to taking set</td>
</tr>
<tr>
<td>Reliability</td>
<td>Contact finish, Stress relaxation</td>
</tr>
<tr>
<td>SI and Current carrying capacity</td>
<td>Electrical and thermal conductivity</td>
</tr>
<tr>
<td>Deflection under load</td>
<td>Modulus of elasticity, yield strength</td>
</tr>
<tr>
<td>Normal force</td>
<td>Modulus of elasticity, mechanical tolerances</td>
</tr>
</tbody>
</table>

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Tutorial: Interconnect Sockets and Applications

Contact material selection criteria:
Section 5
Printed Circuit Board (PCB) & Hardware Requirement
Overview:

- PCB surface finish plays an important role in achieving reliable interconnection between the component or device and bare PCB.
PCB Surface Finishes (Cont’d.)

The primary purpose of the surface finish are:

- Connectivity between the PCB and component devices
- Protect the copper area from oxidation prior to assembly (soldering or using interconnect sockets)
- Promote reliable interconnection for long-term performance
PCB Surface Finishes (Cont’d.)

- Two types of PCB pads:
  1. Copper defined: Solder-mask opening larger than the metal pad
  2. Solder-mask defined: Metal pad larger than the solder-mask opening
Primary Factors in Selecting PCB Finish

- Cost
- RoHS compliant
- Assembly methods
- Durability
- Environment
- Shelf life
- Testability
- Reliability
Types of Surface Finishes

- Standard Hot Air Solder Level (HASL) & Lead-Free HASL
- Organic Solderability Preservative (OSP)
- Immersion silver
- Immersion tin
- Gold:
  - Gold – ENIG - Electroless Nickel Immersion Gold
  - Hard Gold
- Electroless Nickel Electroless Palladium Immersion Gold (ENEPIG)
Standard HASL and Lead-Free HASL

- **Typical finish:**
  - Standard HASL: Typically Tin-Lead (Sn-Pb)
    - Melts at 183°C
    - Shelf life: >12 months (very good)
  - Lead-free HASL: Typically Tin-Copper (Sn-Ag-Cu), Tin-Copper-Nickel (Sn-Cu-Ni)
    - Melts at 217°C to 228°C
    - Shelf life: approx. 12 months

- **Typical thickness:**
  - 70-200 micro-inches
  - IPC specifies complete coverage of SMT pads
Standard HASL and Lead-Free HASL (Cont’d.)

- Advantages:
  - Low cost
  - Readily and widely available
  - Easy to rework – Low cost

- Disadvantages:
  - Uneven surface
  - Not good for direct socket interconnection
  - Not good for thermal shock
  - Potential of solder bridging is high

- High-level typical process:
  - Clean → Microetch → Apply Flux → Solder Dip → Knife leveling → Rinsing
**Organic Solderability Preservatives (OSP)**

- **Typical finish**
  - Organic Solderability Preservatives
  - Applied directly on Copper

- **Typical thickness:**
  - Thin coating: 4-20 micro-inches
  - Finish typically is not specified on the fab drawing
Organic Solderability Preservaties (OSP) (Cont’d.)

- **Advantages:**
  - Lead-free
  - Flat and planar surface
  - Simple process and easy to manufacture
  - Easy to rework – Low cost

- **Disadvantages:**
  - Short shelf life, less than 6 months
  - Exposed Copper during final assembly
  - Bare exposed Copper can cause socket interconnect reliability issues

- **High-level typical process:**
  - Clean → Microetch → Flood OSP → Rinse
Immersion Tin

- **Typical thickness:**
  - 20-50 micro-inches

- **Advantages:**
  - Flat Surface
  - Lead-free
  - Easy to rework
  - 6-month shelf life
Immersion Tin (Cont’d.)

- Disadvantages:
  - High potential for damage during handling
  - Exposed tin can corrode – cause interconnect socket issues during direct socket connection
  - Tin whiskers

- High-level typical process:
  - Clean → Microetch → Predip → Apply Tin → Post dip → Rinse
Gold – ENIG

- Typical thickness:
  - Nickel: 100-200 micro-inches
  - Gold: 3-10 micro-inches

- Advantages:
  - Flat Surface
  - Lead-free
  - Approx. 12-month shelf life
  - Good for direct socket interconnection
Gold – ENIG (Cont’d.)

- **Disadvantages:**
  - Medium to high cost
  - Not reworkable
  - Complicated process

- **High-level typical process**
  - Clean $\rightarrow$ Microetch $\rightarrow$ Catalyst $\rightarrow$ Electroless Nickel $\rightarrow$ Rinse $\rightarrow$ Immersion Gold $\rightarrow$ Rinse
Gold – Hard Gold

- **Typical thickness:**
  - Nickel: 125-150 micro-inches
  - Gold: 25-30 micro-inches

- **Advantages:**
  - Durable surface
  - Lead-free
  - Excellent for direct socket interconnection
  - Long shelf life
Gold – Hard Gold (Cont'd.)

- Disadvantages:
  - Very high cost
  - Extra processing ➔ labor intensive
  - Plating / Bus bars

- High-level typical process:
  - Apply Resist ➔ Clean ➔ Microetch ➔ Electroless Nickel ➔ Rinse ➔ Electrolytic Gold ➔ Rinse ➔ Strip Resist ➔ Clean
Immersion Silver

- **Typical thickness:**
  - 8-15 micro-inches of pure Silver

- **Advantages:**
  - Excellent Solderability
  - Good for direct socket interconnect
  - 6-12-months shelf life

- **Disadvantages:**
  - Sensitive to handling
  - Medium High cost

- **High-level typical process:**
  - Clean → Microetch → Electroless Nickel → Rinse → Immersion Silver → Rinse
Electroless Ni / Electroless Pd/ Immersion Au (ENEPIG)

- Finish/Thickness:
  - Nickel: 120-240 micro-inches
  - Palladium: 4-20 micro-inches
  - Immersion Gold: 3-10 micro-inches

- Advantages:
  - Forms better solder joints with SAC Alloys (Pb free)
  - Palladium eliminates potential corrosion
  - 12-months shelf life
  - Good for direct socket interconnection
Electroless Ni / Electroless Pd/ Immersion Au (ENEPIG) (Cont’d.)

- Disadvantages:
  - Does not form good joints with Sn/Pb alloys
  - High cost

- High-level typical process:
  - Clean → Microetch → Electroless Nickel → Electroless Palladium → Immersion Au
## Comparison of Surface Finishes

<table>
<thead>
<tr>
<th>Type</th>
<th>Planarity</th>
<th>Solderability</th>
<th>Dual Compression Contact</th>
<th>Typical Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>HASL</td>
<td>Poor</td>
<td>Good</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>OSP</td>
<td>Good</td>
<td>Good</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>Immersion Tin</td>
<td>Good</td>
<td>Good</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>Immersion Ag</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Medium</td>
</tr>
<tr>
<td>Gold - ENIG</td>
<td>Good</td>
<td>Good</td>
<td>Very Good</td>
<td>Medium</td>
</tr>
<tr>
<td>Gold-Hard Gold</td>
<td>Good</td>
<td>Good</td>
<td>Excellent</td>
<td>Very High</td>
</tr>
<tr>
<td>ENEPIG</td>
<td>Good</td>
<td>Good</td>
<td>Excellent</td>
<td>High</td>
</tr>
</tbody>
</table>
Overview of PCB Solder-mask

- Primary purpose of solder-mask:
  - Prevent solder shorts under components
  - Prevent socket interconnect shorts
  - Prevent corrosion to underlying circuitry
  - Plating resist for surface finishes

Copper-defined Pads

Mask-defined Pads
Solder-mask Considerations for Socket Connectivity

- Feature size of the solder-mask
- Registration of the solder-mask
- Tolerance on the feature size
- Thickness of the solder-mask
Importance of Solder-mask (SM) Registration

SM tolerance considerations
-- Size
-- Position
-- Thickness (primarily for sockets with short working range)
Parameters to include in fab drawing:

- Alignment hole location
- Socket body/frame
- Mounting hole location
- Surface mount components around the socket body/frame
- Pad diameter
- Surface Finish

Socket outline

Hardware outline

Hardware mounting holes 4X

Surface mount components max height 2mm

Socket alignment holes 2X
Section 6

Electrical Requirements
Impedance of the Socket

- In simple form, impedance (Zo) can be expressed in terms of inductance and capacitance
  - Zo = sqrt (L/C) (lossless impedance equation)
  - L (pin inductance) is a function of the pin geometry, socket pitch and pin length
  - C (pin capacitance) is a function of the pin geometry, socket pitch, pin length and dielectric material

- Impedance matching to system interconnect is essential in minimizing return loss for high-speed applications
Equivalent Circuit of the Socket

Example of BGA socket equivalent circuit (2 pins are shown)

Notation:
- $C_{12a}$ (BGA side): mutual capacitance between adjacent pins
- $C_{12b}$ (PCB side): mutual capacitance between adjacent pins
- $L_1, L_2$: pin inductances
- $M_{12}$: mutual inductance
- $R_1, R_2$: pin resistances

• To accurately model or calculate the impedance of one pin, the surrounding pins need to be accounted for.
Socket Pin Insertion Loss

- Insertion loss is proportional to socket pin length and contact resistance
- The longer the pin, the higher insertion loss for the same material
- The socket material also plays a role in insertion loss
- The lower loss material yields lower insertion loss

Low Insertion is preferred for signal integrity performance
Cross-talk is proportional to the socket pin length
- The longer the pin length, the higher the cross-talk
- It is critical to have a low height socket for high-speed applications
- Socket signal pin-map also plays a critical role in reducing cross-talk
- The higher signal-to-gnd ratio, the lower the cross-talk

Minimal Cross-Talk is preferred for signal integrity performance
Current Carrying Capacity (CCC)

- Current carrying capacity is a very important electrical requirement of a socket. It must meet an application requirement for reliable operations.

- The ability of socket pin contact to carry current is primarily limited by the maximum allowable operating temperature and the pin contact material and contact geometry.
Section 7
Interconnect Socket and System Design
Types of Interconnect Systems

- Two types of interconnect systems

1. Load-based system
   - Required compression of the contact material is achieved by applying measured load using mechanical hardware system
   - Typically used where contacts have low working range

2. Deflection-based system
   - Required compression of the contact material is achieved by using a fixed mechanical stopper
   - Typically used where contacts have high working range
Load-based System

Schematic

Example:
- Polymer socket contacts-- Typical working range < 0.005”
Load-based System (Cont’d.)

- **Primary advantages:**
  - Typically use spring screw retention system
  - Spring accounts for thickness variations in retention system, socket, and package

- **Limitations:**
  - High BOM cost
  - Typically used for sockets with low working range < 200um
Deflection-based System

Example:
-- Pogo pins, stamped and formed contacts -- Typical working range = 0.010”-0.015”
Deflection-based System (Cont’d.)

- **Primary advantages:**
  - Socket acts as compliant member accommodating thickness variation in retention parts
  - Low BOM cost

- **Limitations:**
  - Typically used for sockets with high working range >250um
  - Typically use a pattern for tightening retention screws
  - Require tight thickness and flatness control for retention hardware
Socket Design Parameters

- Thermo-Mechanical
  - Compression and force
  - Cycle life / durability
  - Operating temperature
  - BGA vs LGA
  - Pitch
  - PCB keep-out and plating
  - Hard stops preventing pin over-compression
Socket Design Parameters (Cont’d.)

- Electrical
  - Impedance
  - Inductance
  - Current Carrying Capacity (CCC)
  - Contact resistance

- Cost

- Lead time
Mechanical Hardware Design

- Spring screw retention accommodate z-stack tolerances
- Split loading for bare die devices
  - Periphery loading
  - Heat sink loading
- Stiffener plate insulator openings accommodate surface mount components bottom side of PCB
- Top plate insulator openings accommodate surface mount components on DUT
Mechanical Tolerances

Z-stack tolerance analysis:
- Spring based loading: Spring compressed height variation
- Displacement based loading: Interconnect compressed height variation

XY tolerance analysis:
- Alignment accuracy of interconnect pin to PCB pad
- Alignment accuracy of interconnect pin to Device ball or pad
  - Monte Carlo based: David Shia, Intel Corporation; 2007 Burn-in and Test Socket Workshop
- For HVM test, alignment accuracy and repeatability of handler
Components for Z-stack tolerance analysis:

1. Compressed socket height
2. Package substrate
3. Insulator backing
4. Top plate
5. Spring compressed height

Sectional view
Force-Deflection Analysis

- Finite-Element-Analysis (FEA) is used for:
  - Optimization (thickness) of mechanical hardware components (stiffener plate, top plate, etc)
  - Interconnect array deflection distribution to ensure minimum deflection meets CRES criterion
  - Device warpage under mechanical load, thermal load, etc

- Commercially available tools:
  - ANSYS, Mechanica, Abaqus, etc.
**Force-Deflection Analysis: Example**

- **First order approximation**: individual components of the hardware analyzed for deflection

- **Example: Stiffener plate**
  - **Material**: Steel; $E = 200\,\text{GPa}$; $\nu = 0.3$; Linear Elastic
  - **Force**: 400N
  - **Deflection allowed**: 30um max

*Pressure load*

*Maximum deflection @ center 27um*
Section 8
Socket Interconnect System Testing
Socket Electrical Measurements

- Contact resistance measurement

- Signal integrity S-parameters measurements which contain the following data:
  - Impedance of the socket
  - Insertion loss, return Loss
  - pin-to-pin cross-talk
Contact Resistance Measurement

- Contact resistance board and package are designed to validate retention system and measure pin total resistance (bulk + contact)

- Contact resistance board can be designed with multiple loops
  - Helps in debugging areas which are electrically open
  - Electrical open indicates more PCB or package deflection. Insufficient stiffness of back plate and/or top plate
Contact Resistance Measurement
(Cont’d.)

- Matching daisy-chain package needs to be designed

- Package is soldered down to daisy chain board. Measured resistance is $R_{soldered}$

- Total resistance per pin
  - $(R - R_{soldered})$/number of pins
Contact Resistance Measurement (Cont’d.)

- Custom PCB is designed with 4-wire Kelvin measurement to measure single pin CRES in an array.
Signal Integrity Measurement

- Signal integrity S-parameter measurements characterize the electrical performance of the socket in terms of impedance, insertion loss, return loss and pin-to-pin cross-talk in frequency domain.

- Identify a signal test pattern for testing. Examples below show 2-signal pin and 4-signal pins test patterns.

2-signal pin test pattern with 1:1 signal-to-gnd ratio

4-signal pin test pattern with 1:1 signal-to-gnd ratio
Diagram below shows an example of connecting a VNA (Vector Network Analyzer) test equipment to test fixtures measuring the s-parameters of two socket pins through 4-port measurements.
System Qualification

- System-level validation and testing
  - At normal operating conditions
    - Normal operating conditions; passive heat sink or active heat sink
    - Extreme operating conditions; Thermal margining tool
  - Long-term aging tests
    - Environmental chamber – system is subjected to environmental test conditions
System Qualification (Cont’d.)

- **IN**
- **OUT**

**Thermal margining tool**

**Package**

**Socket**

**System Board**

**Schematic of system test**

**Exploded view of thermal margining tool**
Maintenance: Repair & Cleaning

- **Repair**
  - Polymer sockets are harder to repair for damaged contacts
  - Dual compression pogo-pins can be replaced for bent pins caused by uneven loading

- **Cleaning**
  - Cleaning is essential for good CRES
  - Polymer socket contacts are cleaned using light brush and/or low pressure dry air
  - For HVM high volume test sockets, cleaning is done in-situ using cleaning coupons
  - For BGA devices there is solder migration from solder ball on to pin-tips

![Image of crown contact and slide contact]
Section 9
Real World Example (Team Exercise) & Summary of Technologies
Team Exercise

- Divide into multiple teams (A, B, C & D)

- Each team has a set of requirements

- Discuss within the team and report out the socket choice meeting the requirements. Provide justification

- Make assumptions as needed.
Report Out

Report out must include the following:

- Socket contact element description and material
- Socket contact manufacturing process
- Socket contact plating finish
- PCB requirements (thickness, material, surface finish, plating, etc.)
- Socket to PCB attachment method
- Package to socket attachment method (include any mechanical attachment hardware and manufacturing process of attachment hardware)
- Any custom tooling required
- Any other requirements (Example: cleaning)
Team-A: Requirements

- **Package parameters:**
  - Package size: 12 mm X 12 mm
  - Die size: 5 mm X 7 mm
  - Package pitch: 0.5 mm
  - Package type: Ball-Grid-Array (BGA)

- **Requirements:**
  - Cycle life: minimum 50 cycles (insertions)
  - Operating temperature: 15°C to 75°C
  - Electrical height: < 1.5 mm
  - Socket attachment type: Surface-mount (solder or dual compression)
  - Mechanical hardware: Standalone retention solution
  - Prototype lead time: < 4 weeks
  - Production cost: < $300/socket including hardware
  - Production order quantity: 1K
Team-B: Requirements

- **Package parameters:**
  - Package size: 12 mm X 12 mm
  - Die size: 5 mm X 7 mm
  - Package pitch: 0.5 mm
  - Package type: Ball-Grid-Array (BGA)

- **Requirements:**
  - Cycle life: >100K cycles (insertions)
  - Operating temperature: -10°C to 100°C
  - Electrical height: < 5 mm
  - Socket attachment type: Surface-mount (solder or dual compression)
  - Mechanical hardware: Handler compatible for cycling
  - Prototype lead time: < 10 weeks
  - Production order quantity: 100
  - Production cost: <$5K/socket
Team-C: Requirements

**Package parameters:**
- Package size: 12 mm X 12 mm
- Die size: 5 mm X 7 mm
- Package pitch: 0.65 mm
- Package type: LGA pads with ENIPEG plating

**Requirements:**
- Cycle life: minimum 20 cycles (insertions)
- Operating temperature: -10°C to 100°C
- Electrical length: < 6 mm
- Socket attachment type: Surface-mount (solder or dual-compression)
- Mechanical hardware: Standalone retention
- Prototype lead time: < 24 weeks
- Production order quantity: 1 million
- Production cost: <$10/socket
Team-D: Requirements

- **Package parameters:**
  - Package size: 12 mm X 12 mm
  - Die size: 5 mm X 7 mm
  - Package pitch: 0.5 mm
  - Package type: Ball-Grid-Array (BGA)

- **Requirements:**
  - Cycle life: 10K cycles (insertions)
  - Operating temperature: -10 °C to 100°C
  - Electrical length: < 10 mm
  - Socket attachment type: Through-hole
  - Mechanical hardware: Handler compatible for cycling
  - Prototype lead time: < 10 weeks
  - Production cost: $100/socket
  - Production order quantity: 5,000
## Summary of Socket Key Technologies

<table>
<thead>
<tr>
<th>Factors</th>
<th>Polymer-based</th>
<th>Screw-Machine</th>
<th>Stamped-formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical material</td>
<td>Silicon rubber filled with metal powder</td>
<td>Beryllium Copper</td>
<td>Beryllium Copper</td>
</tr>
<tr>
<td>Scalability &lt;0.4mm pitch</td>
<td>Very Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Electrical height</td>
<td>Low</td>
<td>Medium to High</td>
<td>Medium</td>
</tr>
<tr>
<td>Cost/pin</td>
<td>Medium</td>
<td>Medium to High</td>
<td>Low to medium</td>
</tr>
<tr>
<td>Wiping action</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Compliance/working range</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Cycle life (insertion/removal)</td>
<td>Low</td>
<td>High</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Solderability to PCB</td>
<td>Poor</td>
<td>Good</td>
<td>Very Good</td>
</tr>
</tbody>
</table>
### Summary of Socket Contact Key Technologies (Cont’d.)

<table>
<thead>
<tr>
<th>Factors</th>
<th>Polymer-based</th>
<th>Screw-Machine</th>
<th>Stamped-formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Vs Dual compression</td>
<td>Dual only</td>
<td>Single and dual</td>
<td>Single and dual</td>
</tr>
<tr>
<td>Material compression set</td>
<td>Medium to high</td>
<td>None</td>
<td>Very low</td>
</tr>
<tr>
<td>Typical lead time</td>
<td>Short</td>
<td>Medium</td>
<td>Medium to long</td>
</tr>
<tr>
<td>Volume application</td>
<td>Low to Medium</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Tooling/NRE</td>
<td>Low</td>
<td>Medium</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Real-world application</td>
<td>Validation</td>
<td>Test</td>
<td>Production/Burn-in</td>
</tr>
<tr>
<td>Cycle time to design</td>
<td>Short to medium</td>
<td>Short to medium</td>
<td>Long</td>
</tr>
<tr>
<td>Serviceability</td>
<td>Low (difficult)</td>
<td>High (easy)</td>
<td>Low(difficult) to medium</td>
</tr>
</tbody>
</table>
Section 10
Design to Production Activities
&
Check-list
<table>
<thead>
<tr>
<th>#</th>
<th>ACTIVITY</th>
<th>RELATIVE TIMELINE (WEEKS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Understand product requirement</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Create product requirement document</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Research and define type of socket contacts and select</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Design socket and mechanical hardware based on PRD -- Include FEA analysis</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Define PCB requirements and special mechanical tolerances, if any</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Design test boards for testing sockets for continuity, environmental conditions, signal integrity and contact resistance</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Create detailed mechanical drawings including tolerances</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Obtain quotes, order and receive parts -- Socket, hardware, test boards, etc.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Assemble and test socket assemblies for continuity using test boards</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Test for resistance stability with number of insertions</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Conduct signal integrity (SI) tests using SI test boards</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Conduct environmental tests -- temperature and humidity cycling</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Revise socket and hardware designs per test results as required</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Finalize drawings and release design for production</td>
<td></td>
</tr>
</tbody>
</table>

Time line depends on the complexity and number of design revisions.
# Process Steps and Check-list

<table>
<thead>
<tr>
<th>No</th>
<th>Process Step</th>
<th>Check-List</th>
</tr>
</thead>
</table>
| 1  | Understand product requirement (PRD) | - Electrical and Signal Integrity (SI)  
- Socket cycle life  
- Socket and hardware cost  
- Environmental |
| 2  | Create Product Requirement Document (PRD) | - Socket cycle life  
- Socket cost  
- Environmental test conditions  
- SI requirements  
- Keep-Out Volume requirements both for socket and hardware  
- PCB requirements |
| 3  | Research and define type of socket contact to be used and select | - Review supplier socket specifications – cycle life, cost, signal integrity data  
- Get preliminary quotes  
- Select the best option based on PRD requirements |
| 4  | Design socket and mechanical hardware based on PRD | - Force-deflection analysis done to ensure robust and right material selected for hardware design  
- SI analysis done to ensure socket meets electrical requirements  
- Right amount of socket element deflection  
- Right mechanical tolerances and ensure hardware is manufacturable |
## Process Steps and Check-list

<table>
<thead>
<tr>
<th>No</th>
<th>Process Step</th>
<th>Check-List</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Define PCB requirements and special mechanical tolerances, if any</td>
<td>- PCB surface finish&lt;br&gt;- PCB tolerances -- both absolute and positional&lt;br&gt;- Solder-mask requirements, if any&lt;br&gt;- PCB board material – dielectric constant (Dk), Dissipation factor (Df)&lt;br&gt;- Socket/hardware keep-out volume defined that meets PRD</td>
</tr>
<tr>
<td>6</td>
<td>Design test boards for testing sockets</td>
<td>- Daisy-chain test boards for contact resistance measurement&lt;br&gt;- Daisy-chain packages or test boards (simulating package) for contact resistance measurement&lt;br&gt;- SI measurement test boards</td>
</tr>
<tr>
<td>7</td>
<td>Create detailed mechanical drawings including tolerances</td>
<td>- Hardware material call-out (e.g. Al, Steel, etc.)&lt;br&gt;- Positional and absolute tolerances&lt;br&gt;- Surface finish/plating of the material</td>
</tr>
<tr>
<td>8</td>
<td>Obtain quotes, order and receive parts – socket, hardware, test boards</td>
<td>- Obtain quote for prototypes and production – sockets, hardware, test boards.&lt;br&gt;- Order both sockets, hardware and test boards</td>
</tr>
</tbody>
</table>
### Process Steps and Check-list

<table>
<thead>
<tr>
<th>No</th>
<th>Process Step</th>
<th>Check-List</th>
</tr>
</thead>
</table>
| 9  | Assemble and test socket assemblies for continuity using test boards         | - Inspect all sockets and hardware parts to ensure they meet the specifications  
- Inspect test boards for tolerances and surface finish |
| 10 | Check for resistance stability with number of insertions                    | - Record resistance/contact  
- Disassemble and reassemble sockets and component/device  
- Record resistance  
- Repeat disassembly and reassembly and record resistance at every cycle  
- Determine the socket life based on the PRD requirement of change in resistance from the initial resistance |
| 11 | Conduct Signal Integrity (SI) tests                                         | - Socket Impedance  
- Socket pin insertion loss  
- Socket pin-to-pin cross talk  
- Current carrying capacity/pin |
| 12 | Conduct environmental tests – temperature and humidity cycling              | - Extreme high and low temperature testing depending on the application. Also, duration depends on application  
- Thermal shock – temperatures depend on the application  
- Humidity – typically 85%RH |
## Process Steps and Check-list

<table>
<thead>
<tr>
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<th>Process Step</th>
<th>Check-List</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Revise socket and hardware designs per test results as required</td>
<td>- Changes made to the socket and socket hardware per test results</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Force-deflection analysis and SI analysis redone if required</td>
</tr>
<tr>
<td>14</td>
<td>Finalize drawings and release design for production</td>
<td>- Keep-out volume defined and made sure it meets PRD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Positional and absolute tolerances defined both for PCB and mechanical hardware</td>
</tr>
<tr>
<td></td>
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<td>- PCB surface finish/plating material defined</td>
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<td></td>
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<td>- Final check to ensure design meets product requirement document (PRD)</td>
</tr>
</tbody>
</table>
Section 11
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