



连接器设计系列培训

连接器设计介绍

- 连接器的功能/性能要求
- 连接器的结构/材料
- 连接器测试



连接器功能/性能要求

- 连接器的功能定义-需完成的任务,满足的要求.

An electronic connector is an electromechanical system which provides a separable interface between two subsystems of an electronic system without an unacceptable effect on the performance of the system.

高频高速性能 机械性能 电气性能

- All connectors perform the basic function of bridging a gap in a circuit to allow the flow of energy. However connectors are specially designed to optimized mechanical and electrical performance.

- 功能/作用-可分离性-可分离的次数/插拔寿命/EOL接触电阻:正向力状况,界面磨损状况.

维修/维护/保养;升级;外围设备扩展;组装(零部件可在不同场合组装);手提;设计灵活性;避免焊接连接的损坏...

- 功能/作用-可连接性-连接力(插入力)的大小-功能增加,pin增加.
- 连接的可接受性-不产生不可接受的影响
- 连接器的性能特点/性能要求的应用依赖性.



连接器高频高速传输

高频高速信号的两个方面:

- **信号的完整性(SI)**——简单地说,是指信号在电路中以正确的时序和电压作出响应的能力,如波形的完整性,信号相位的正确性,是信号传输器件的固有特征,这些固有特征决定于组件的几何结构和材料性能. 目的使被接受的信号接近被发送的信号. 信号完整性问题的首要任务是解决信号传输的匹配问题, 常见指标:
a, 特性阻抗; b, 回波损耗(RL); c, 插入损耗; d, 反射系数; e, 电压驻波比; f, 差模公模转换(差分信号)
- **电磁波的兼容性(EMC)**——消除或限制外来电磁波, 噪声对自身信号的干扰或自身信号对外在的电磁波的干扰. 常见手段包括: (A) 屏蔽, (B) 滤波, (C) 接地等方式及 (E) 控制电磁波的干扰和 (F) 射频干扰的做法. 常见指标有:
A, 串扰; B, 屏蔽效果; C, RF泄漏;
- 信号完整性和电磁波兼容性都是设计的重要方面. 电磁波兼容性好的系统往往不干扰或不遭受周围其他设备的干扰. 差分信号相对于单端信号就显示不干扰或不遭受周围其他设备的干扰的优越性, 故在高速连接器的应用越来越普遍.
- 高速数字电子系统的发展和繁衍使EMC和SI成为主要的连接技术.
- 除非传输线的结构极为简单, 高频高速信号适合应用仿真技术来分析-有限元分析



传输线

特征阻抗:

ENCNN

信号在传输的过程中，如果传输路径上的特征阻抗发生变化，信号就会在阻抗不连续的结点产生反射。

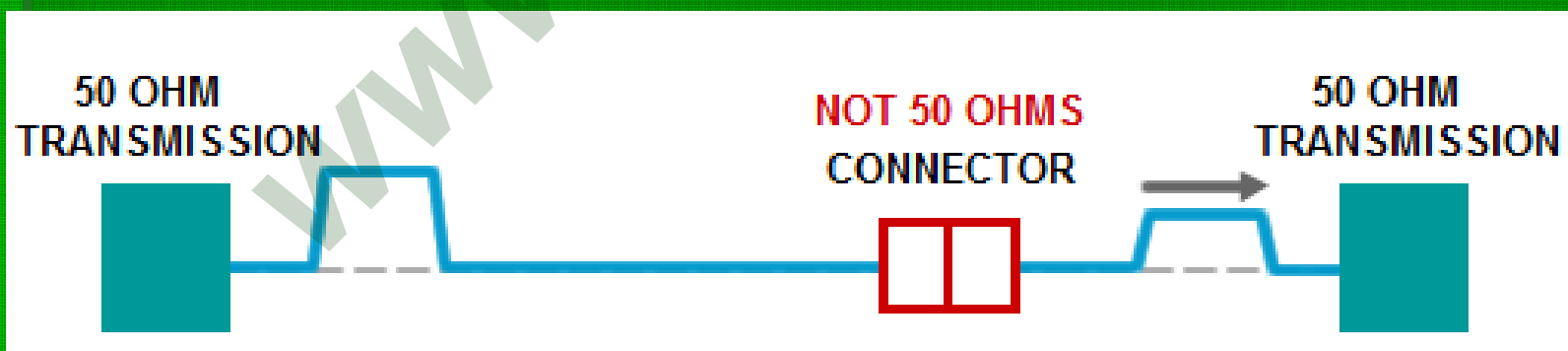
Impedance matching

Good signal integrity through a channel requires impedance that is constant. Ideally, every component in a channel offers the same impedance. This is known as impedance matching. A channel that is matched throughout is said to have controlled impedance.

Common impedance sources in a channel include trace width changes, poor signal routing, bad terminations, a PCB layer change, return path gaps, and, of course, connectors. A conductor like a wire or trace is relatively smooth and offers little resistance or impedance. But think about mated connectors and all the potential "bumps" a signal may see as it traverses an interconnect.

Controlling impedance

Impedance is primarily a function of the cross-section area of the conductor and the distance between the signal and ground.

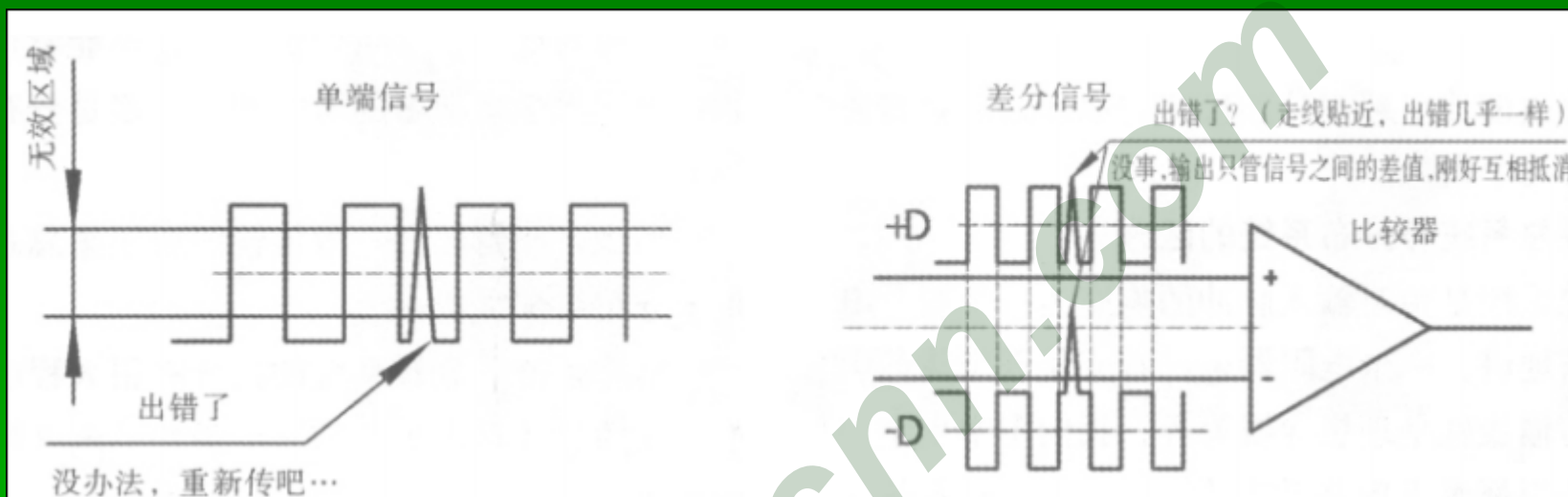




传输线

ENCNN

差分传输线
(通常称为平衡式):



传统的单端信号数据传输方式, 对于干扰信号无抵抗力, 一旦信号受到外界的干扰发生畸变, 最终的信号就会受到严重影响. 差分传输线适用于对噪声隔离和改善时钟频率要求较高的情况. 在差分模式中, 传输线路是成对布放的(一对并行耦合的传输线), 两条线路上传输的信号电压, 电流值相等, 但相位(极性)相反(一根传输信号, 另一根传输它的互补信号). 最终输出这对差分信号的比较值. 由于信号在一对迹线中进行传输, 在其中一条迹线上出现的任何电子噪声与另一条迹线上出现的电子噪声完全相同(并非反向), 两条线路之间生成的场将相互抵消-它通过两路信号的相减实现减小外界干扰的目的, 其结构天生具有抗干扰能力. 因此与单端非平衡式传输线相比, 只产生极小的地线回路噪声, 并且减少了外部噪声的问题. 当设备内电子器件越来越多, 频率速率越来越高, 干扰也随之越来越严重, 单端信号已达上限, 只能采用差分信号进行数据传输.



连接器性能特点

- 连接器性能特征反应了产品在为该应用场合而设计的机械应力和环境应力,也体现了诸如电气性能的长期稳定性.

机械应力---物体由于外因(受力、湿度变化等)而变形时,在物体内部各部分之间产生相互作用的内力,以抵抗这种外因的作用,并力图使物体从变形后的位置回复到变形前的位置.

环境应力---是指温度,湿度,振动,冲击等环境条件对产品的作用.

Among application environment are (1) mechanical environment, which, in addition to (a) mating considerations, includes (b) vibration and (c) fretting; (2) the thermal environment, which includes both (a) temperature and (b) temperature variations (including I thermal expansion mismatch, II corrosion, III diffusion and IV IMC); and (3) chemical environment, which includes (a) humidity as well as (b) potential corrosive species such as I chlorine, II sulfur and III oxygen.

连接器性能特征基于:

- 环境状况-影响或决定如下3项的性能水平
- 电气特性
- 机械特性
- 兼容性

性能特性的定义:

- 测试方案(test schedule)
- 测试条件的苛刻性(severity of test)
- 测试终了的状态
- 特性的不同容差(different/closer tolerance on characteristics)
- 环境测试的不同苛刻度



连接器性能

■ 工作环境

- 温度和温度范围
- 稳态湿度和湿热
- 低气压
- 液态浸泡和抵御
- 工业环境腐蚀

■ 电气性能

- 间隙和爬电距离
- 耐压
- 载流能力
- 接触电阻
- 绝缘电阻
- 传输特性

■ 机械性能

- 机械操作
- 配合力和拔出力
- 端子的固定
- 防错/防呆系统
- 轴向静载荷
- 冲击和振动

Encnn enables connection!

www.encnn.com



连接器性能

■ 兼容性

- 安装(inter-mountability)
- 互配(inter-mateability)
- 互换(interchangeability)

Example:

- contact design;
 - - shape and dimension of mechanical interface;
 - - material specifications;
 - - retention information of loose-part or removable contacts;
- - locking device;
- - mounting information.
- Additional compatibility requirements may be defined in the product detail specification to fulfill compliance with automatic mounting, assembling and solder/solder-less termination tools.

Encnn enables connection!

www.encnn.com



连接器性能

兼容性等级

Level 1 - Inter-mountable

This level standardizes only overall dimensions and mounting dimensions on printed board or panel cut-out and cable termination assembly. Connectors from different sources are not necessarily inter-mateable. Information required in a detail specification in order to satisfy to this level is:

For printed board connectors:

- printed board layout;
- board distances and orientation (parallel or perpendicular);
- panel cut-out and location, if applicable.

For free cable connector, cable termination assembly characteristics shall be specified.

Level 2 - Inter-mateable

This level standardizes only dimensions of electrical and mechanical interfaces. electrical, mechanical and climatic performances of connectors from different sources, when mated, are not fully guaranteed.

Level 3 - Inter-mateable and inter-mountable

This level standardizes mounting dimensions, electrical and mechanical interface and overall dimensions. Electrical, mechanical and climatic performances of connectors, from different sources, when mated, are not fully guaranteed.

Level 4 - Interchangeable

This level standardizes all the elements guaranteeing compliance of the electrical, mechanical and climatic performances of mated connector when individual connectors halves are from different sources

Encnn enables connection!

www.encnn.com



连接器性能

性能等级

连接器的性能等级反应了产品在测试时能承受的环境应力和机械应力的组合状况和诸如长期稳定性的电气特征

Example: 气候性等级

Preferred temperature ranges and severities of the damp heat, steady state tests have been selected. Any combination of these elements may be used, and should be written in the format: for example 10/070/04, in the applicable sectional and detail product specifications.

Lower temperature °C	Upper temperature °C	Damp heat, steady state Days
-10	70	4
-25	85	10
-40	100	21
-55	125	56
-65	155	
	175	
	200	
	260	

Encnn enables connection!

www.encnn.com



连接器性能要求/应用依赖性

■ **Electric**

- Contact resistance
- Dielectric resistance
- DWV/voltage proof
- Rating current
- Transient current
- Overload current
- Rating voltage
- Temp range/T-rise

■ **Electronic**

- Impedance
- Crosstalk
- Noise
- Delay
- Skew
- Rise time
- Loss (e.g. IL, RL)

■ **Mechanical**

- Durability
- Mating/un-mating force
- Normal force
- IP, flammability
- Termination strength
- Vibration/shock

■ **Structural**

- Mechanical robust
- Installation
- Size, density, weight
- Good feeling of mating/un-mating
- Mistake-proof
- Guide pin
- Easy for cable assembly
- Easy for maintenance
- Contact sequencing
- Alignment
- Wiping

■ **Environmental**

- Humidity
- Mixed flow gas
- Atmospheric contamination
- Solder-ability
- Soldering heat resistance
- Solvent resistance
- Corrosion resistance

■ **Special application requirements:**

- Humidity/Water proof; sealing...
- Switching
- Filtering.

Encnn enables connection!

www.encnn.com

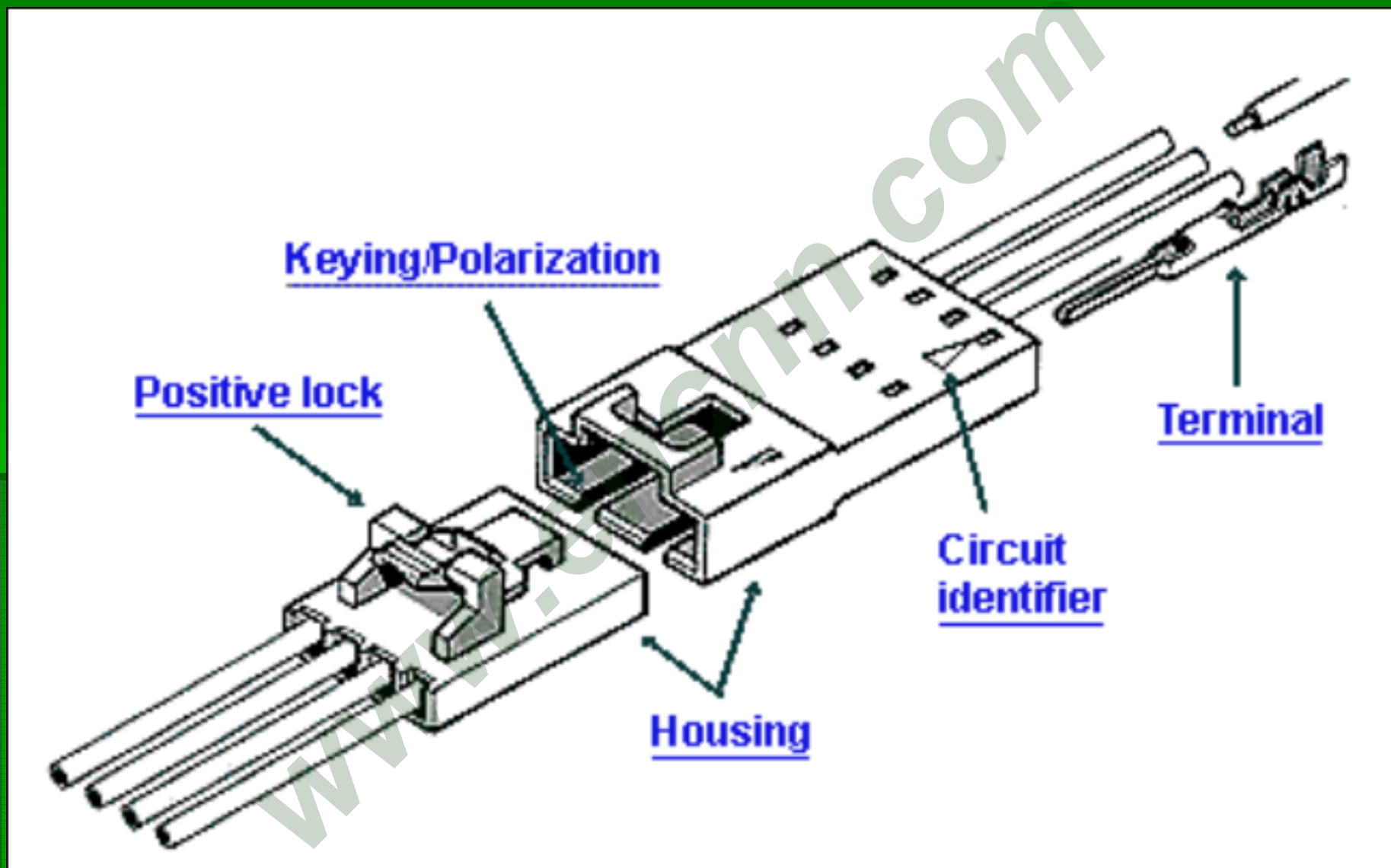


连接器的结构/材料

- 连接器的结构
- 连接器的界面
 - 可分离界面
 - 永久连接界面
- 连接器的电镀
- 连接器弹片/端子
- 连接器的塑胶.



连接器的结构图





连接器的结构图

Encnn

配合的锁扣

In some cases, friction between housing may be adequate, while, in other scenarios, a locking mechanism is used for mating security.

很多连接器具有锁扣结构以使公母连接器的配合更可靠 - 连接器对不会因外界轻微的干扰而脱落, 也能抵御使用要求的一定机械载荷, 此外锁扣结构也能给使用者一种听觉和(或)手感信息: 连接器已互配好或连接器对配合已脱开



Ramp Lock



Friction Lock



Bayonet Latch



Screw Lock

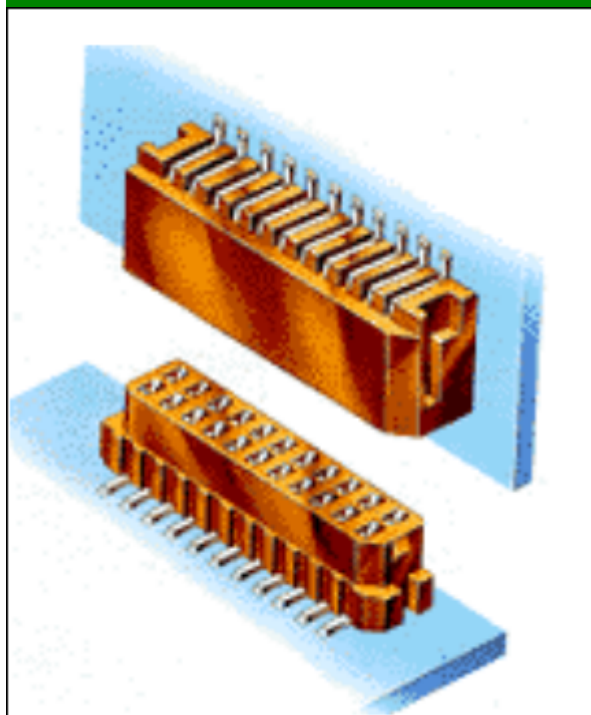
Encnn enables connection!

www.encnn.com

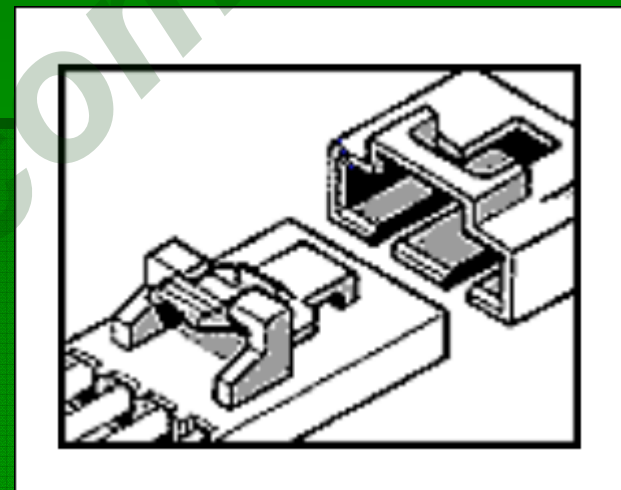


连接器的结构图

配合防错/防呆结构



配合防错/防呆结构防止连接器插错或配合错误, 保证只有正确的方位连接器才能配合, 避免误配而造成损失(如电路烧坏, 设备损坏, 甚至人身安全问题.) 有些连接器甚至因为配合防错结构而得名, 如D-sub.



Encnn enables connection!
www.encnn.com



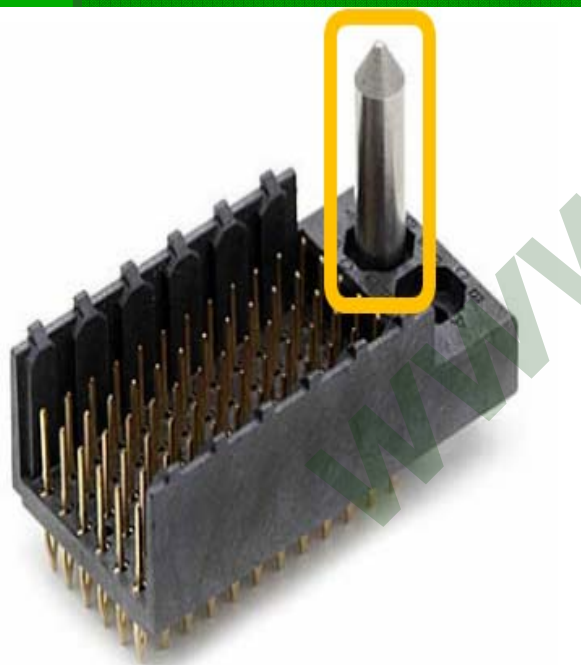
连接器的结构图

配合防错/防呆结构

A latch slot or tab is used for mating alignment or polarization



Polarization can be enabled using different connector components



A connector shape can be used for polarization with mating connector.



Encnn enables connection!
www.encnn.com



连接器的结构-- keying结构

Tab and slot



Color coding.

ENCNN enables connection!
www.encnn.com



连接器的结构 - 导向结构和盲插结构

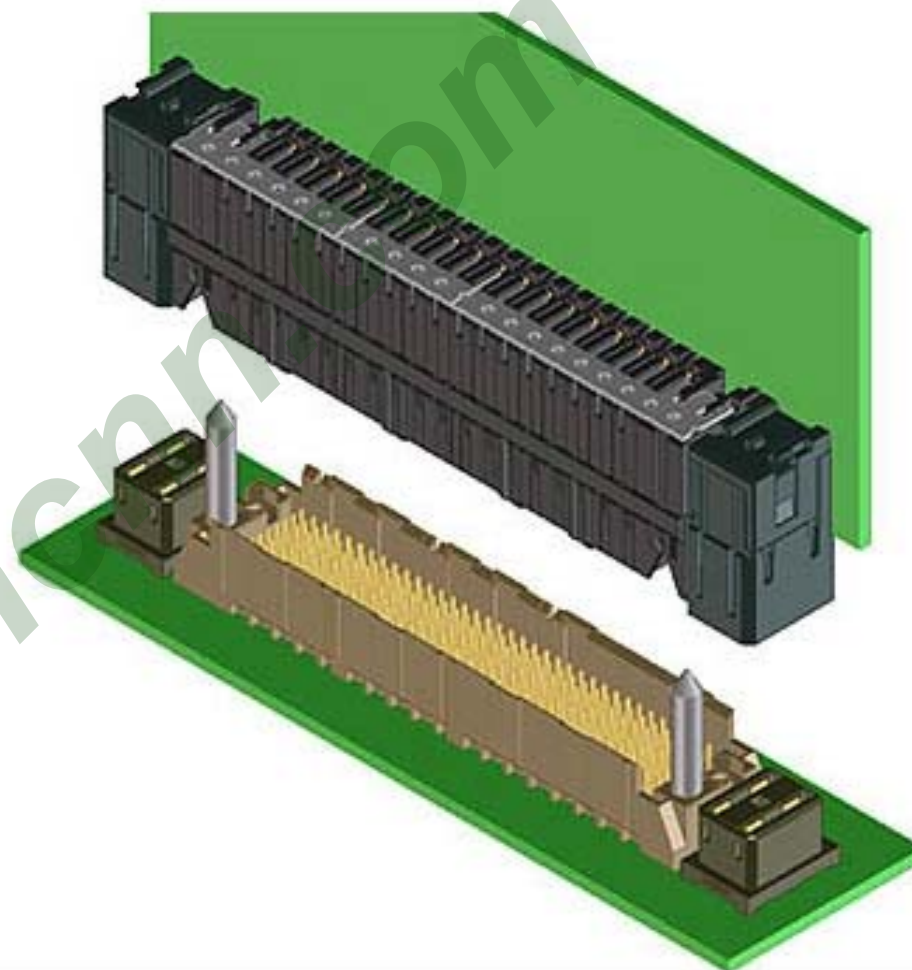
Like polarization and keying, guidance also aligns connector pairs properly before mating.

A metal guide post with a beveled tip is integrated into the housing or as optional module.

The post aligns with a bushing on the connector. There may be a post on one connector end or both.

Properly aligning two mating connectors can be a challenge in locations that are hard to see or difficult to reach, such as inside a vehicle dashboard.

Blind mating designs facilitate mating with a large flange that funnels one connector into another for accurate alignment before mating.



Guide Post



连接器的结构 - 密封连接

Some connector housing are sealed to protect terminals and electrical connections from moisture and other contaminants.

Seals are rubber gaskets that compress to close any openings where assembled components meet

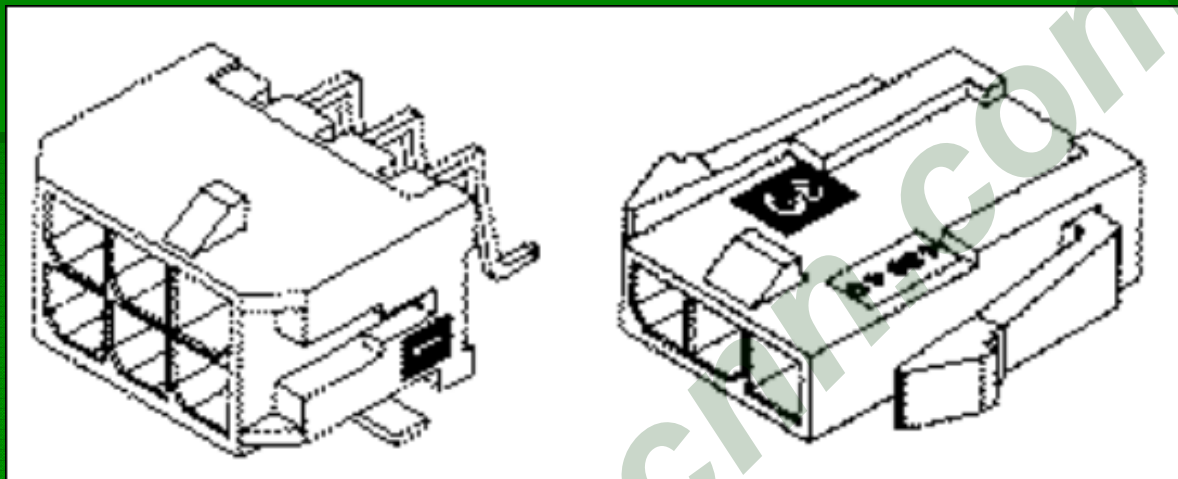
A matte seal has pliable holes through which terminated contacts are inserted and sealed around the wires. The plastic plugs on each end compress to form airtight assembly





连接器的结构图

电路指示符



有不少连接器是用于连接多路线路(甚至几百上千的线路). 在连接器上表示出每路电路能极大方便客户, 甚至也能起到防错的功能. 表示的方法有数字, 字母, 颜色(color coding)等

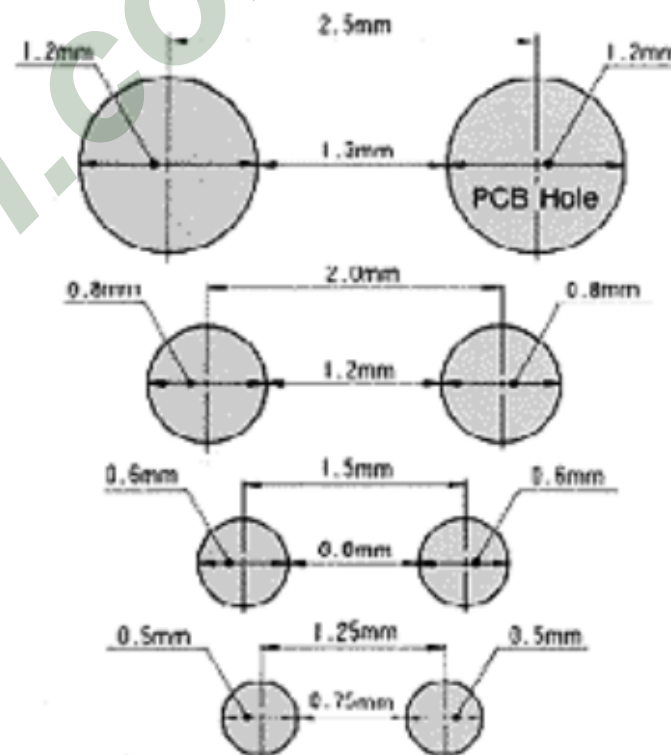
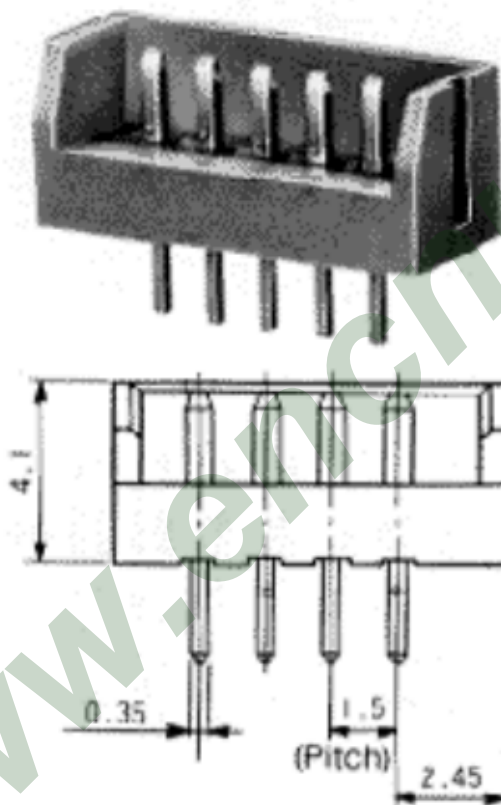


连接器的结构图

连接器的间距

Pitch

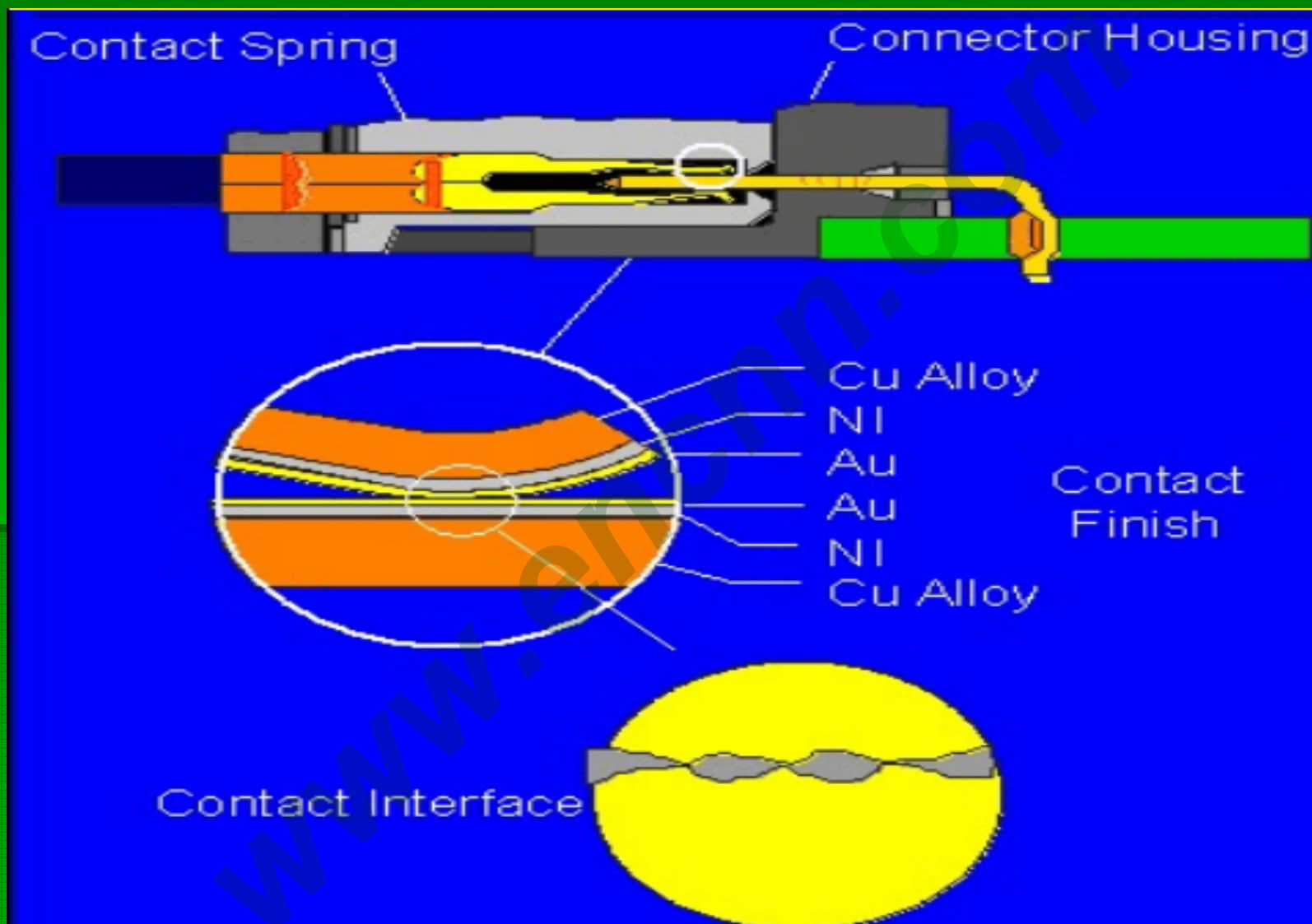
Pitch is the distance from center-to-center between adjacent conductors. For pitches below 1.25mm, soldering may be difficult, so techniques like surface mounting are used. Pitch also affects [arcing](#), which can cause interference between adjacent conductors in a connector.



The board-to-board connector on the left has a pitch of 1.5mm. On the right are some common pitch measurements.



连接器的结构图



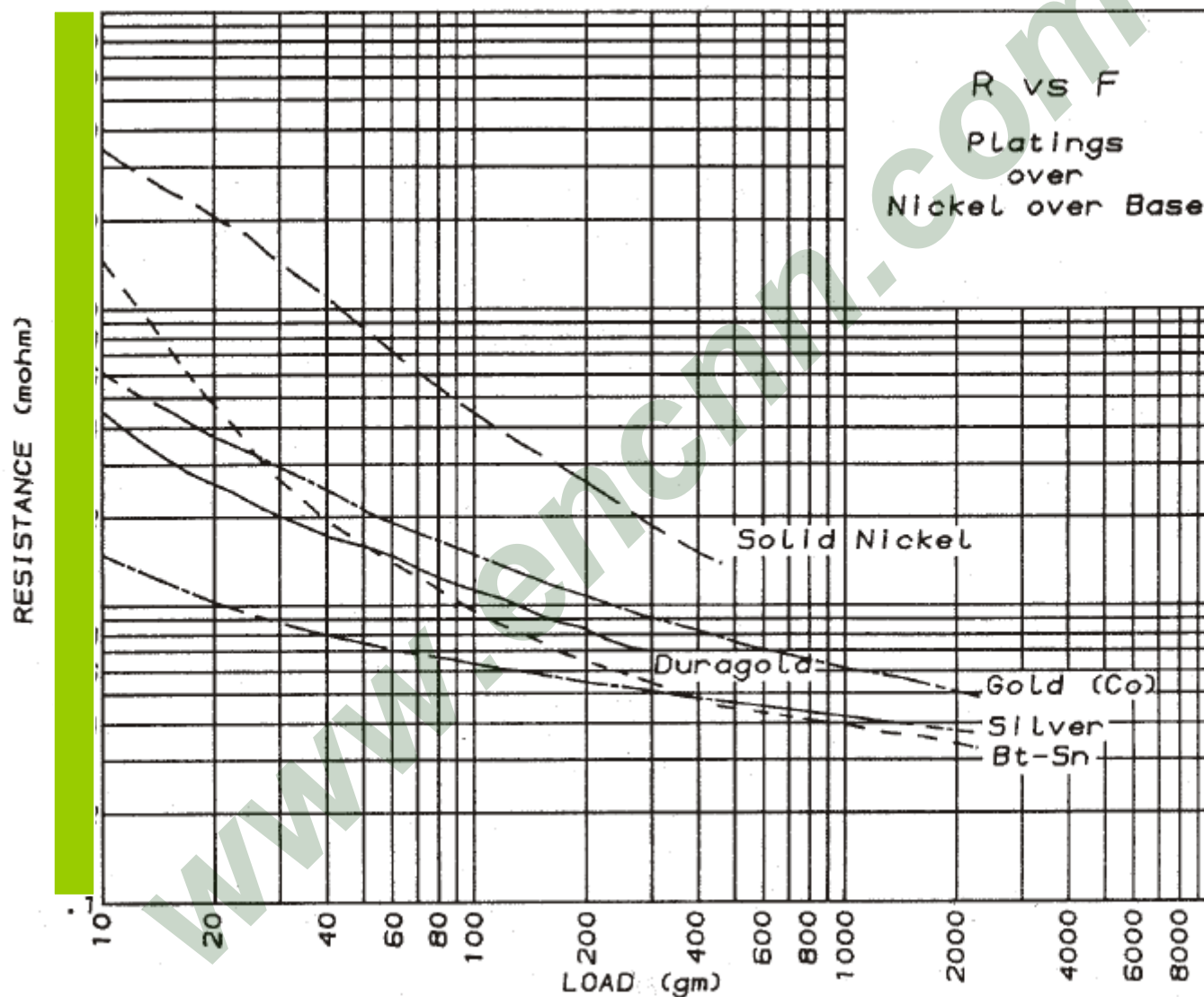


界面的意义及影响

- 决定接触电阻的大小, 稳定性.
- 决定插拔次数 (durability)
- 性能退化 (degradation) 的位置
- 理解连接器工作原理的基础
- 理解连接器设计标准的基础



接触电阻/镀层/正向力关系



Encnn enables connection!

www.encnn.com



连接器插拔寿命评估

插拔寿命评估因素:

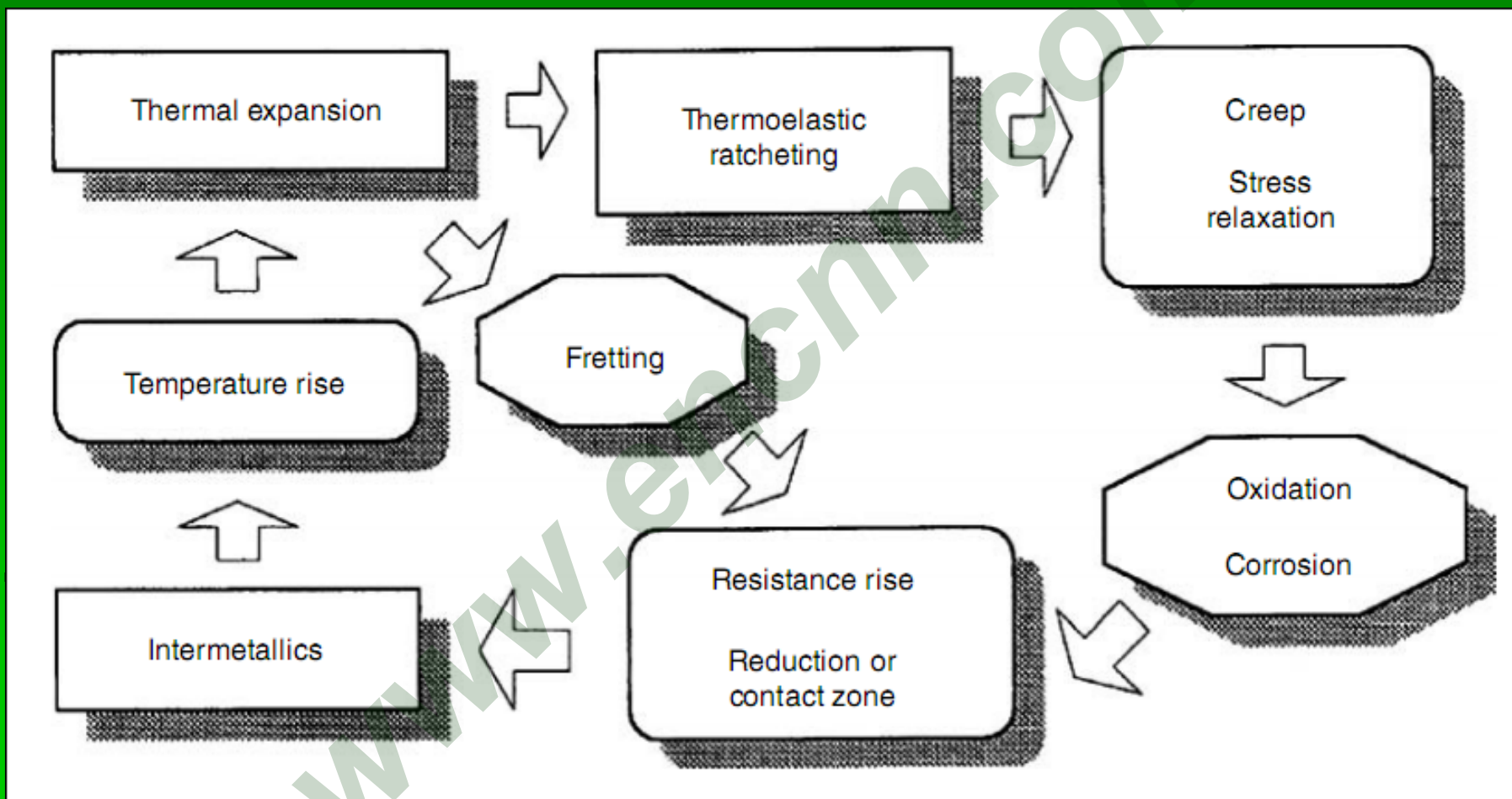
- 产品机械载荷状况, (e. g. 应力分布/屈服状况...).
- 产品工作温度(环境温度+产品温升).
- 端子材料的温度性能:
 - 材料牌号
 - 材料质别(temper)
 - 应力释放状况
- 镀层的温度性能:
 - 表层的氧化情况及孔隙性
 - 里层的电镀规格(是否镍底及厚度)

- 镀层的磨损性能:

正向力, 镀层的种类, 硬度, 表面粗糙度, 润滑状况, 赫兹应力, 是否镍底及厚度, 公母连接器镀层的匹配性.

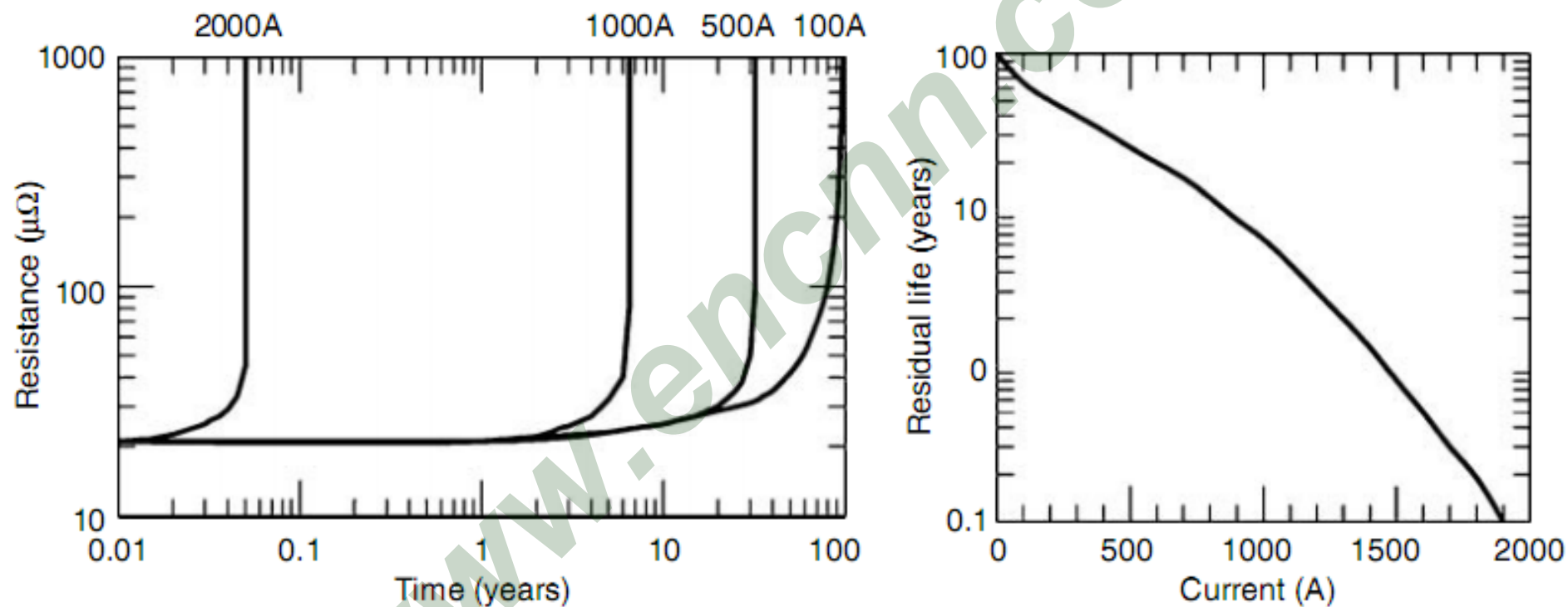


连接器界面的失效形式





连接器界面的失效形式

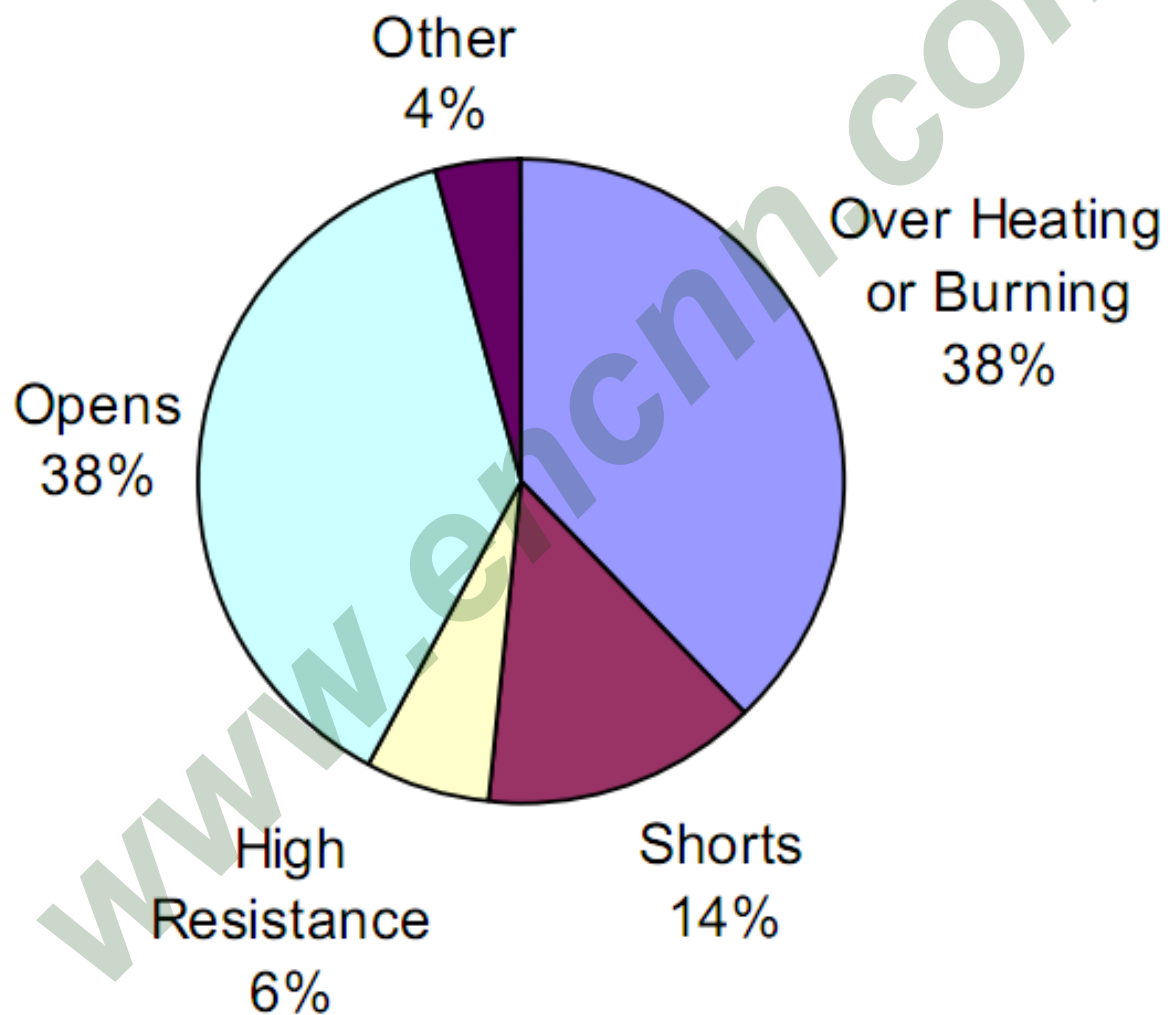




连接器不良统计

连接器
开路
(open)
和过热
(overheat)
失效统计

Failures Investigated by Type

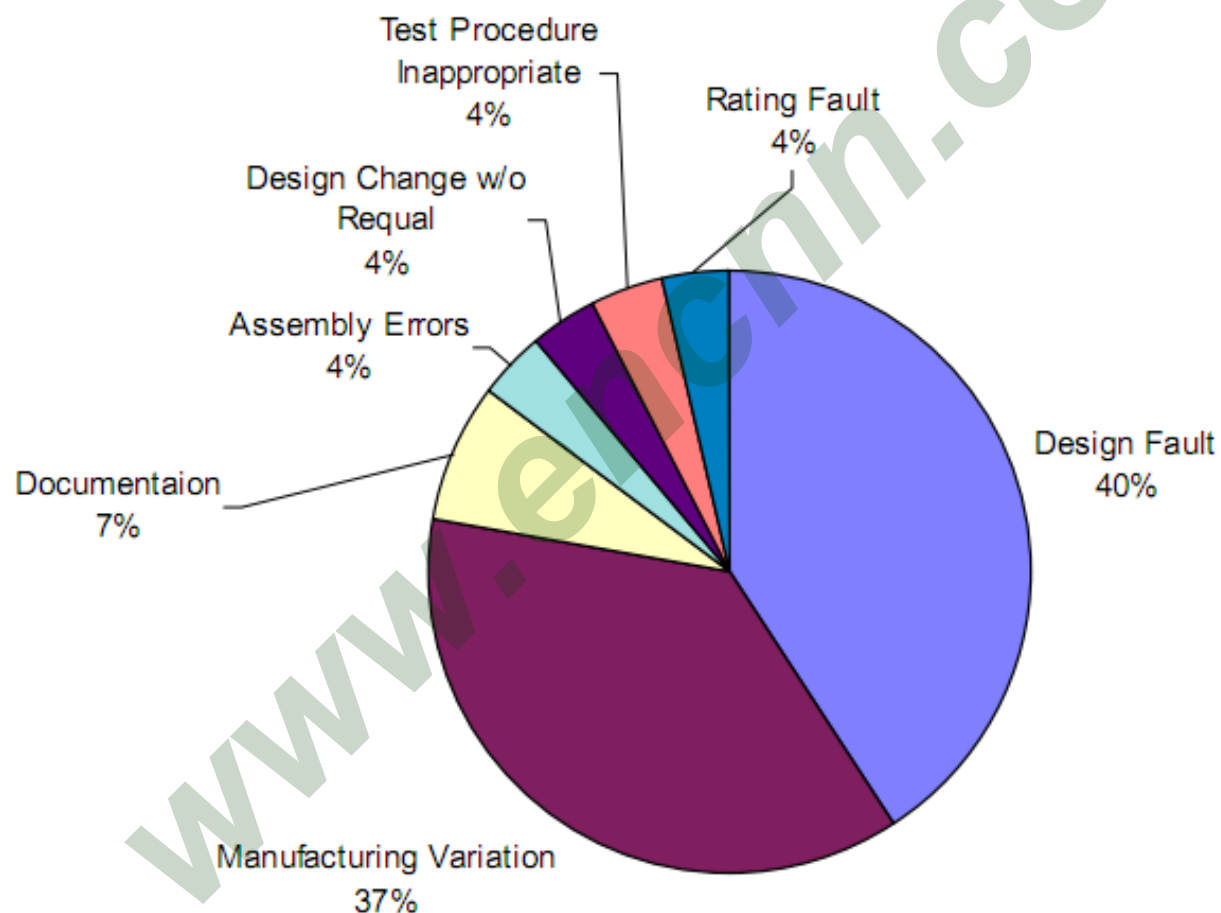




连接器不良统计

连接器开路 (open) 和过热 (overheat) 失效统计

Opens/Overheat - Causes (27 Cases)





触点微观分析 (1)

任何经过精细加工的名义平面,实际上都是粗糙不平.当接触时,即使外加很大的接触力在接触表面也只有少数的点(小面)实际发生真正的接触,这些实际接触的小面承受全部的外加接触力.由于金属表面一般都覆盖着不导电的氧化膜或其它种类的膜,因而在实际接触小面内,只有少部分膜被压破的地方才能形成金属与金属的直接接触,电流实际上只从这些更小的金属接触点通过.

机械接触斑点:

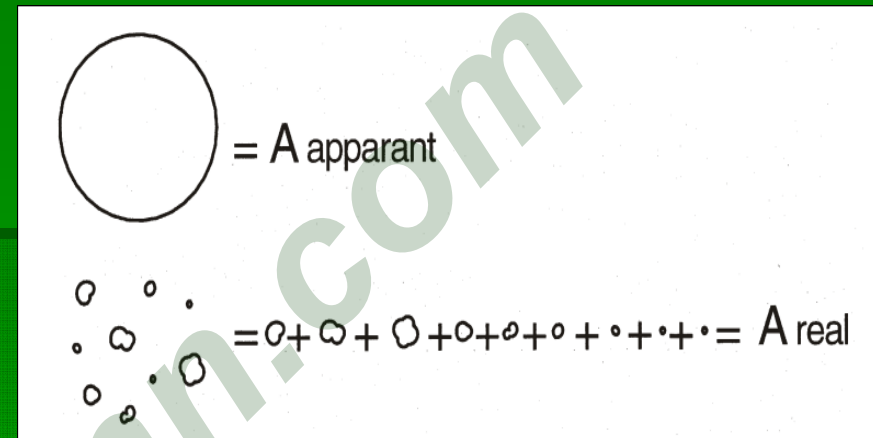
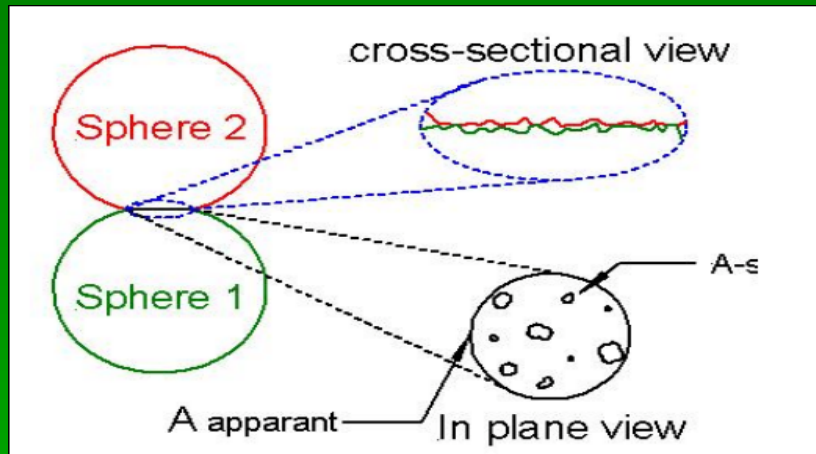
实际发生机械接触的小面简称“接触斑点”

导电斑点/a asperity:

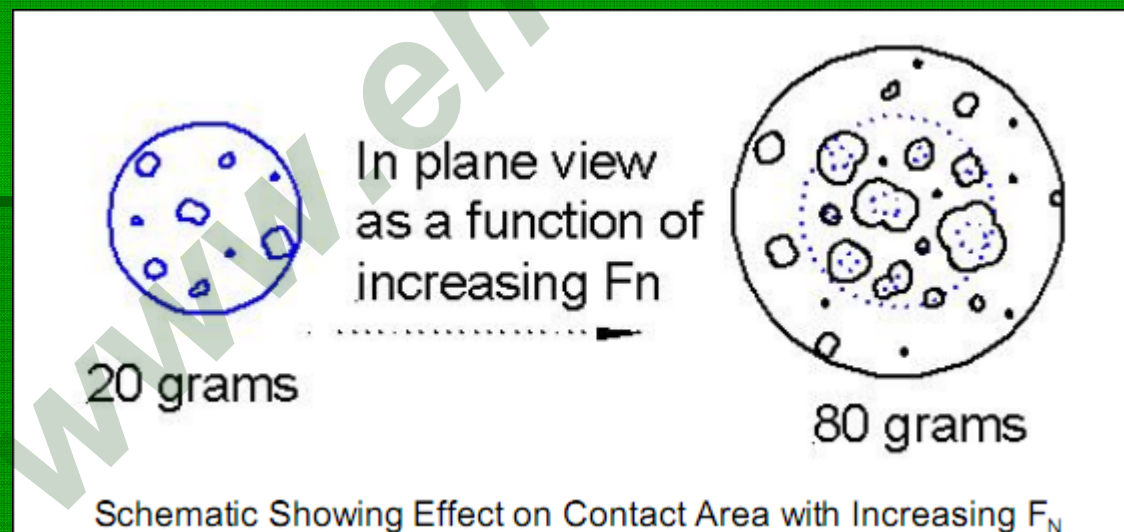
形成金属接触或准金属接触的更小的面(实际传导电流的面)或称为a斑点.



触点微观分析 (2)

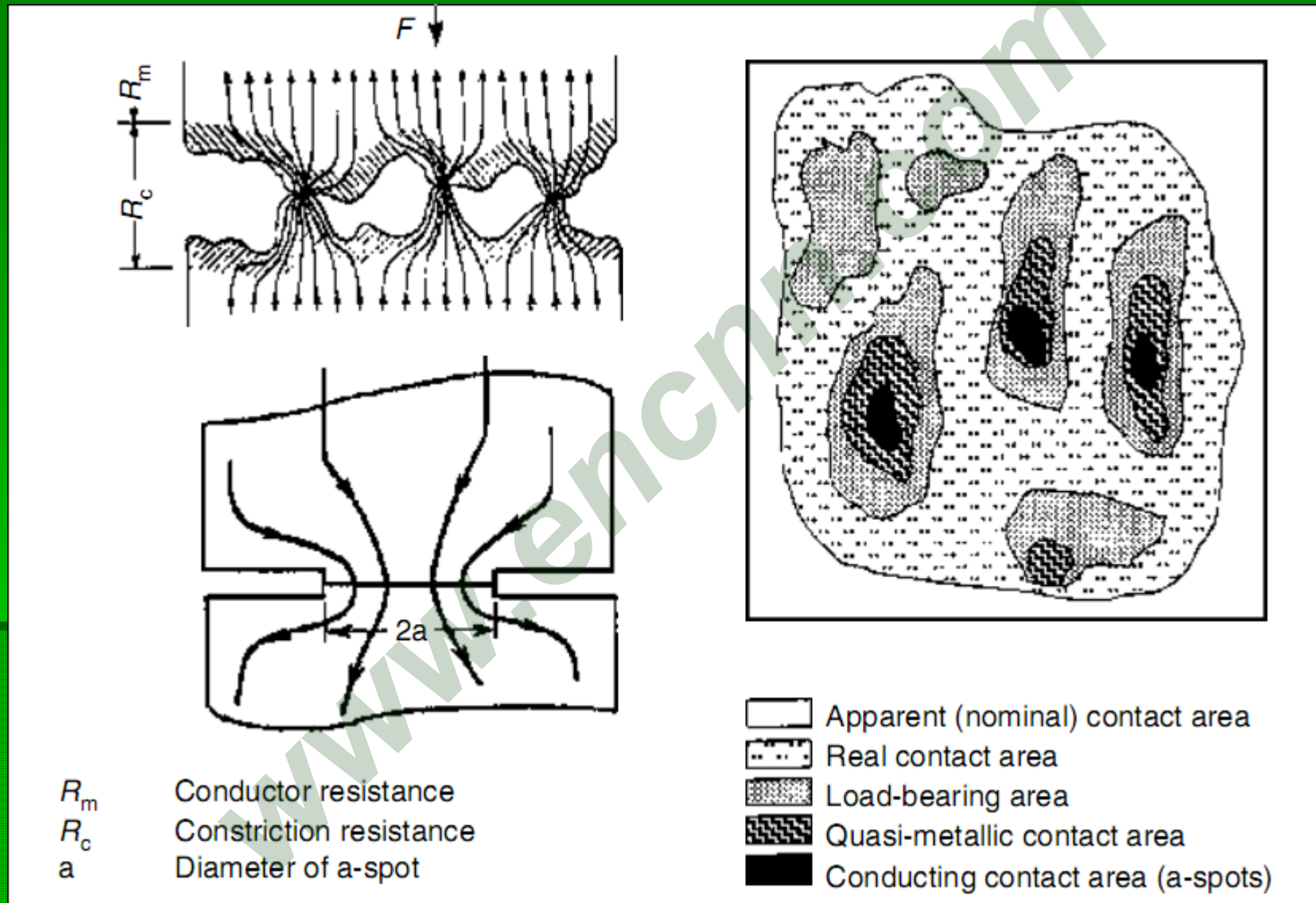


触点的分布,数量及触点区域的变形程度受影响于两表面的粗糙度,表面几何形状以及正向力.





触点微观分析 (3)





触点微观分析 (4)



Optical Micrograph of a Cross-section of a Turned Surface after Indentation by a Spherical Indenter. The Turned Surface Morphology Is Retained Even after Extensive Plastic Deformation of the Surface. The Persistence of Surface Features Is Shown.⁴

即使表面产生严重变形峰谷特点不会消失

- 实际接触面积只取决于正向力.
- 硬度数值便是例证(如100gf/平方毫米, 100gf产生1平方毫米变形).



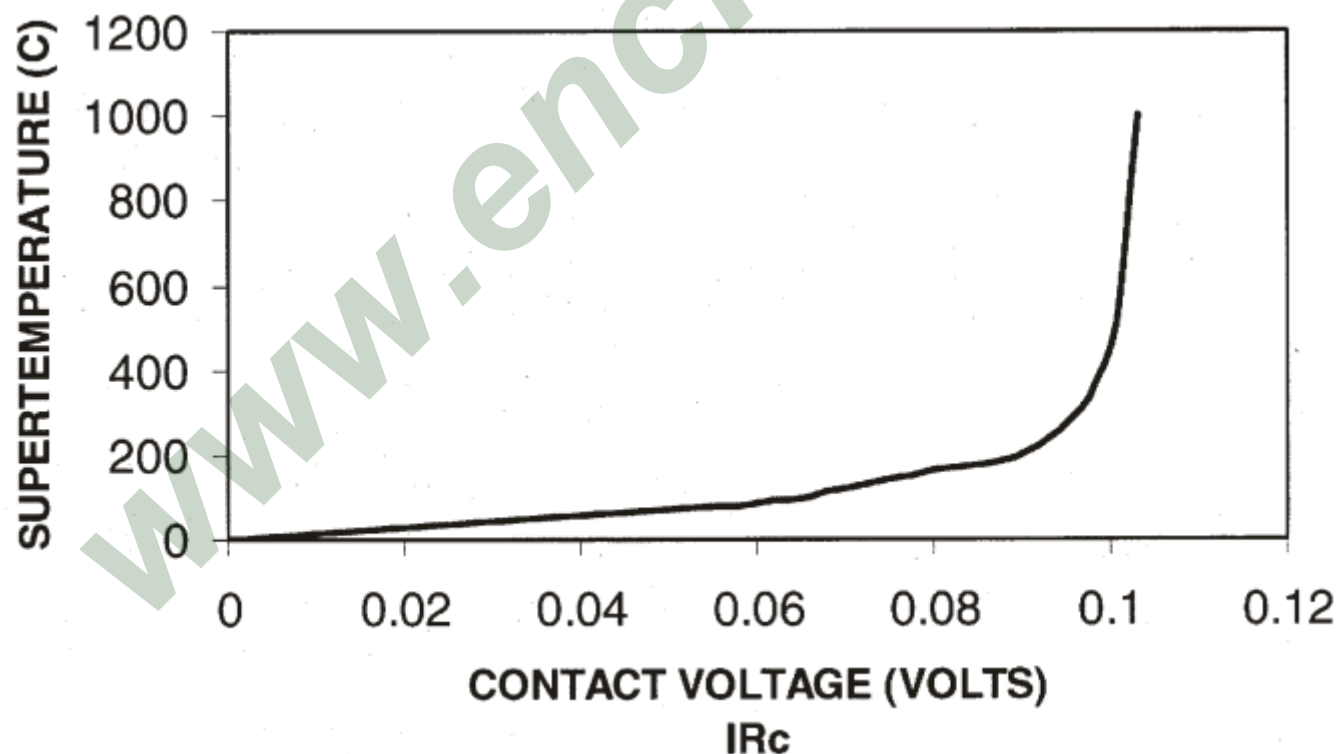
电源端子的设计依据/标准

体电阻电流的设计依据: 温升和电压降

界面电阻电流的设计依据: 如下(安全系数较高)

Separable interfaces:	$T_s < 1$ degree Centigrade
Permanent interfaces:	$T_s < 0.1$ degree Centigrade
End of Life (EOL):	$T_s < 10$ degrees Centigrade
Transients:	$T_s < 90\% T_s$ (melting)

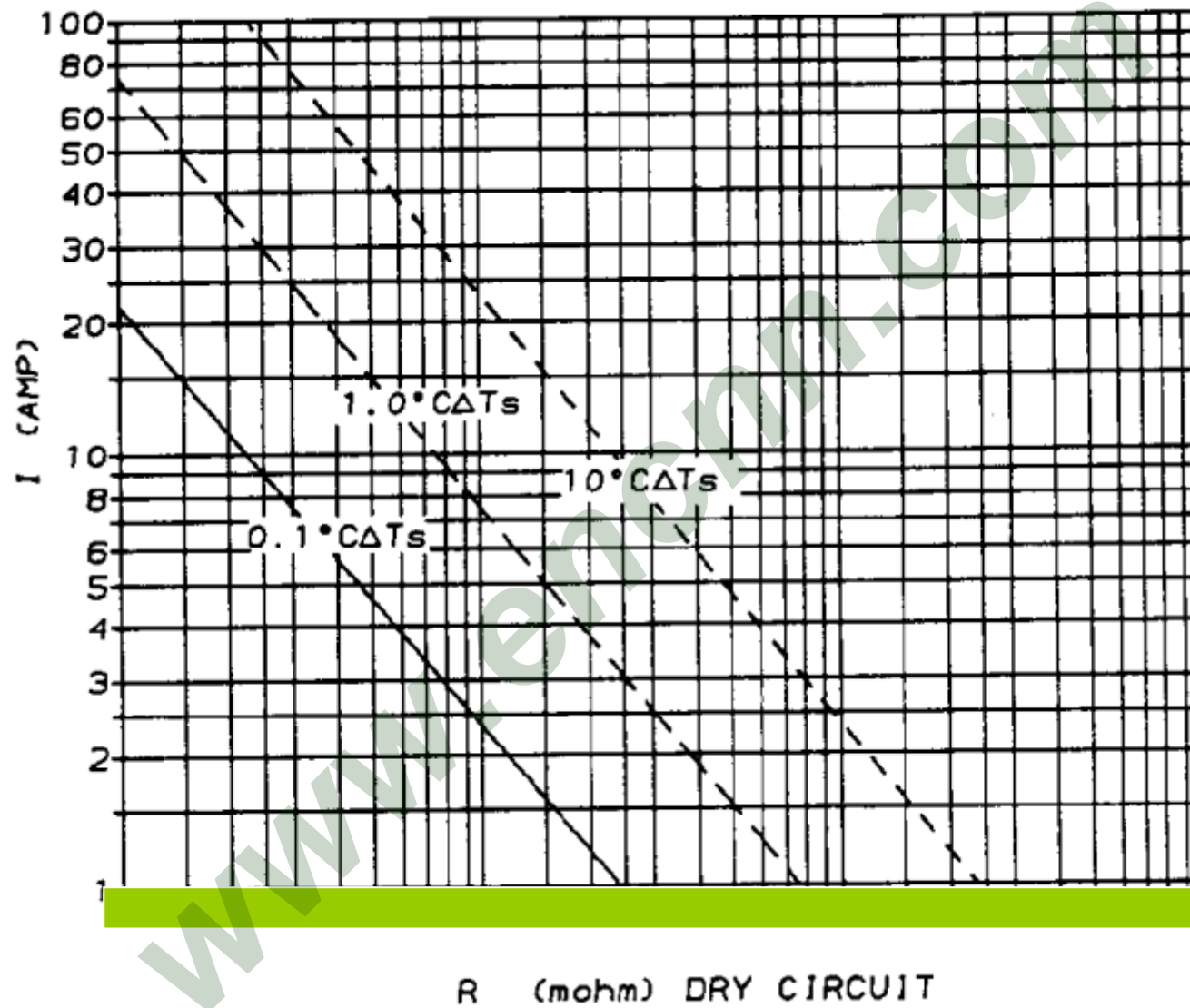
界面超高温与电压降的关系





电源端子的设计依据/标准

Encnn



Encnn enables connection!
www.encnn.com



可分离界面

- 连接器配合时形成
- 界面结构的决定因素：
 - 端子的几何形状
 - 正向力
 - 端子镀层.



永久连接方式

■ 连接器与电子子系统/信号(能量)载体的连接

■ 机械方式:

- Wire wrapping

- IDC

- Crimp

- Press fit

- Piercing

■ 冶炼方式 (Metallurgical)

- Soldering

- Welding

- Brazing.

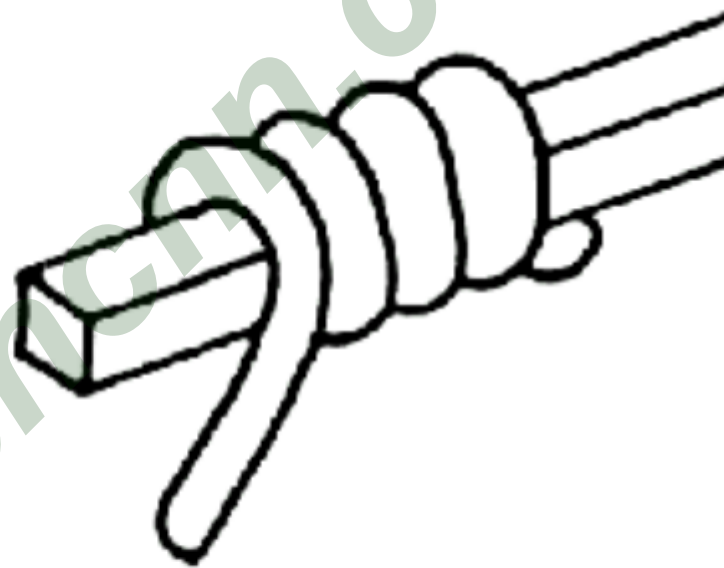


Wire wrap connection

Termination—Wire Wrap

In wire wrap termination, square posts (also called *wire-wrap tails*) are wrapped with discrete, solid copper wire conductor. Square posts are used because the corners "bite" into the wire, improving strength and contact.

The common industry practice is to use one wrap (shown), two wrap, or three wrap terminations.

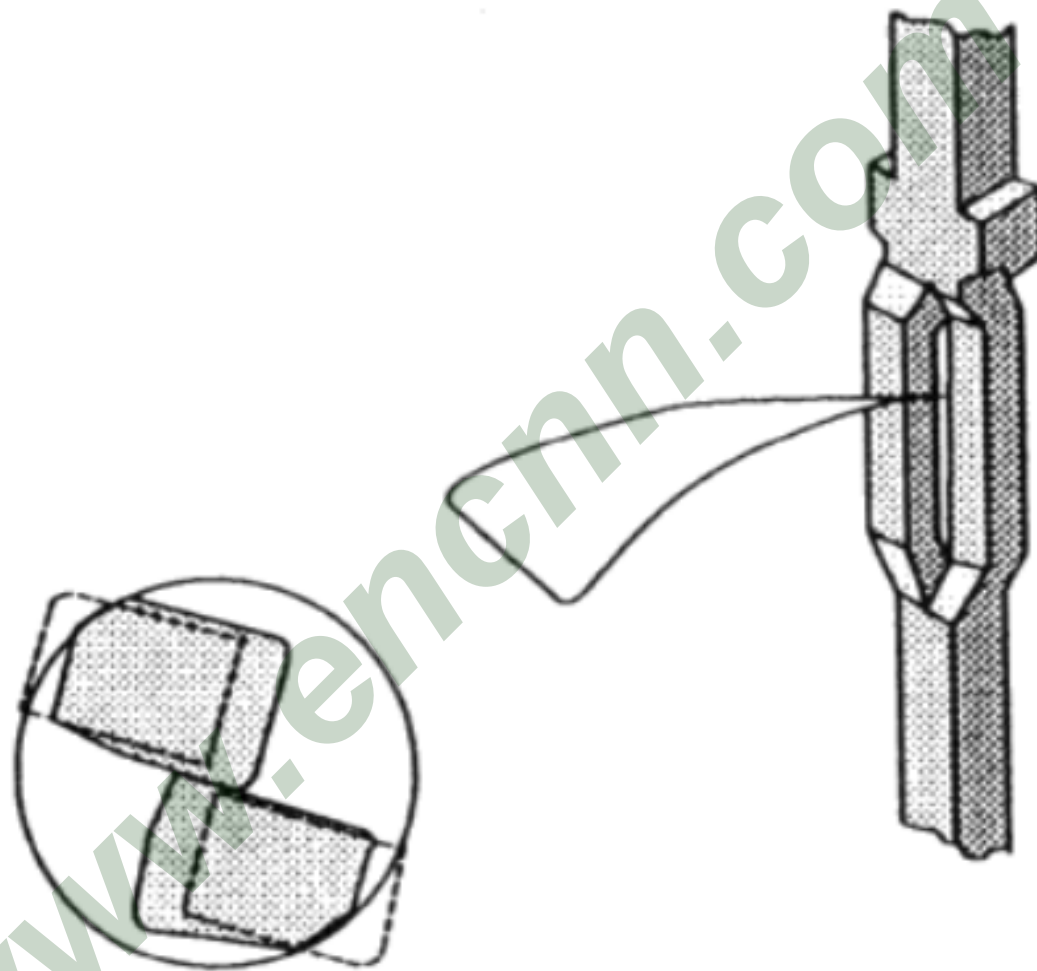


Wire wrap is often used for prototyping, as engineers experiment with various configurations.



Press fit 连接

Encnn



Cross Section of Pin Before Insertion -----

Encnn enables connection!
www.encnn.com



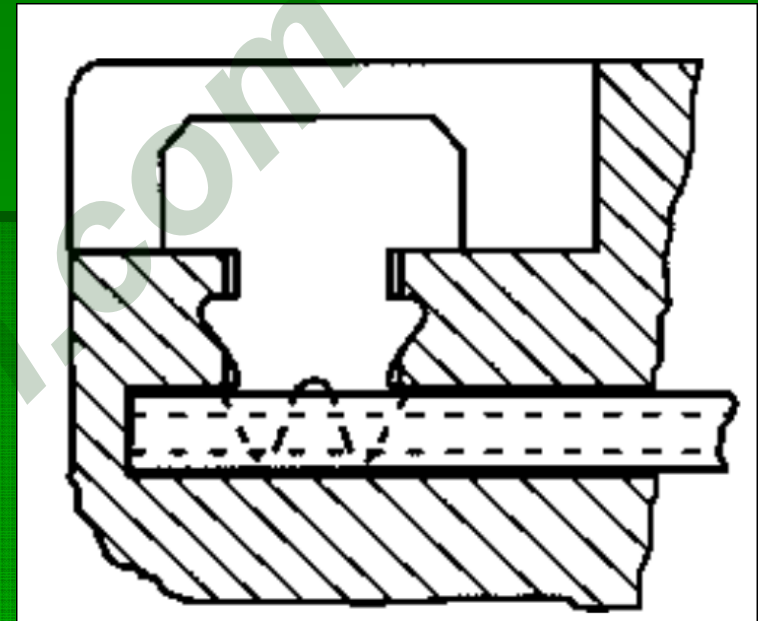
Piercing 连接

ENCNN



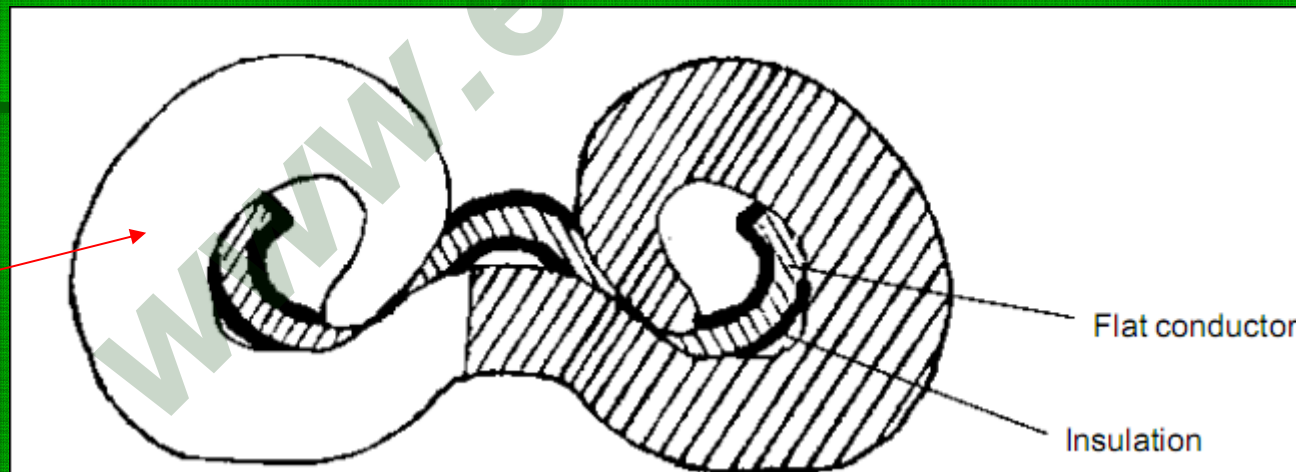
terminal

Stranded
conductors



insulation

terminal



Flat conductor

Insulation

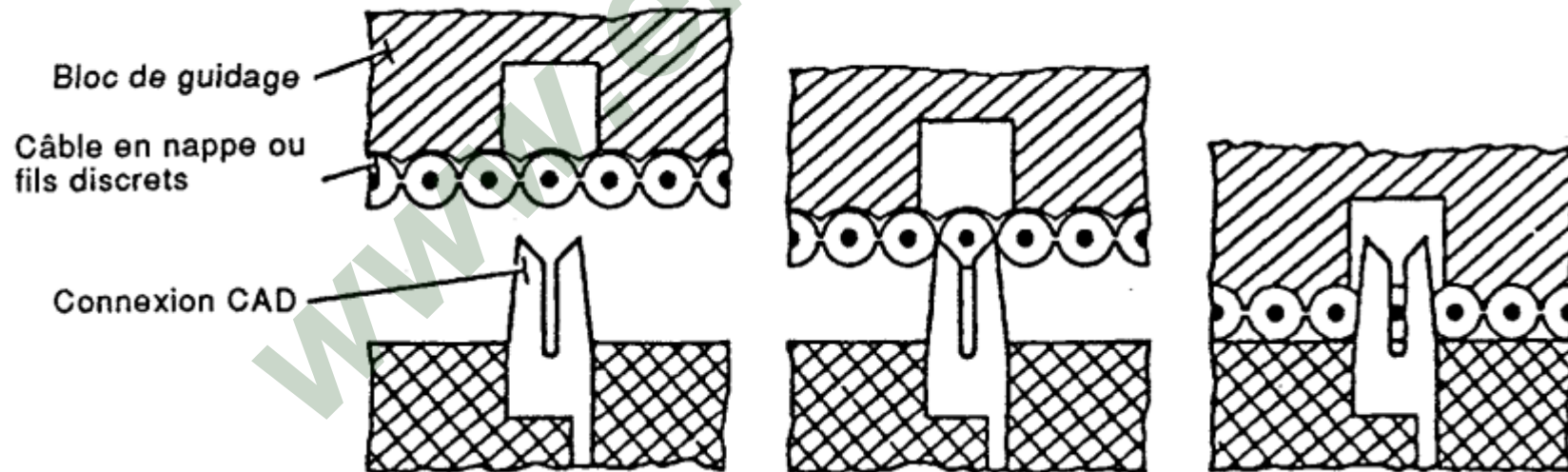
ENCNN enables connection!
www.encnn.com



IDC



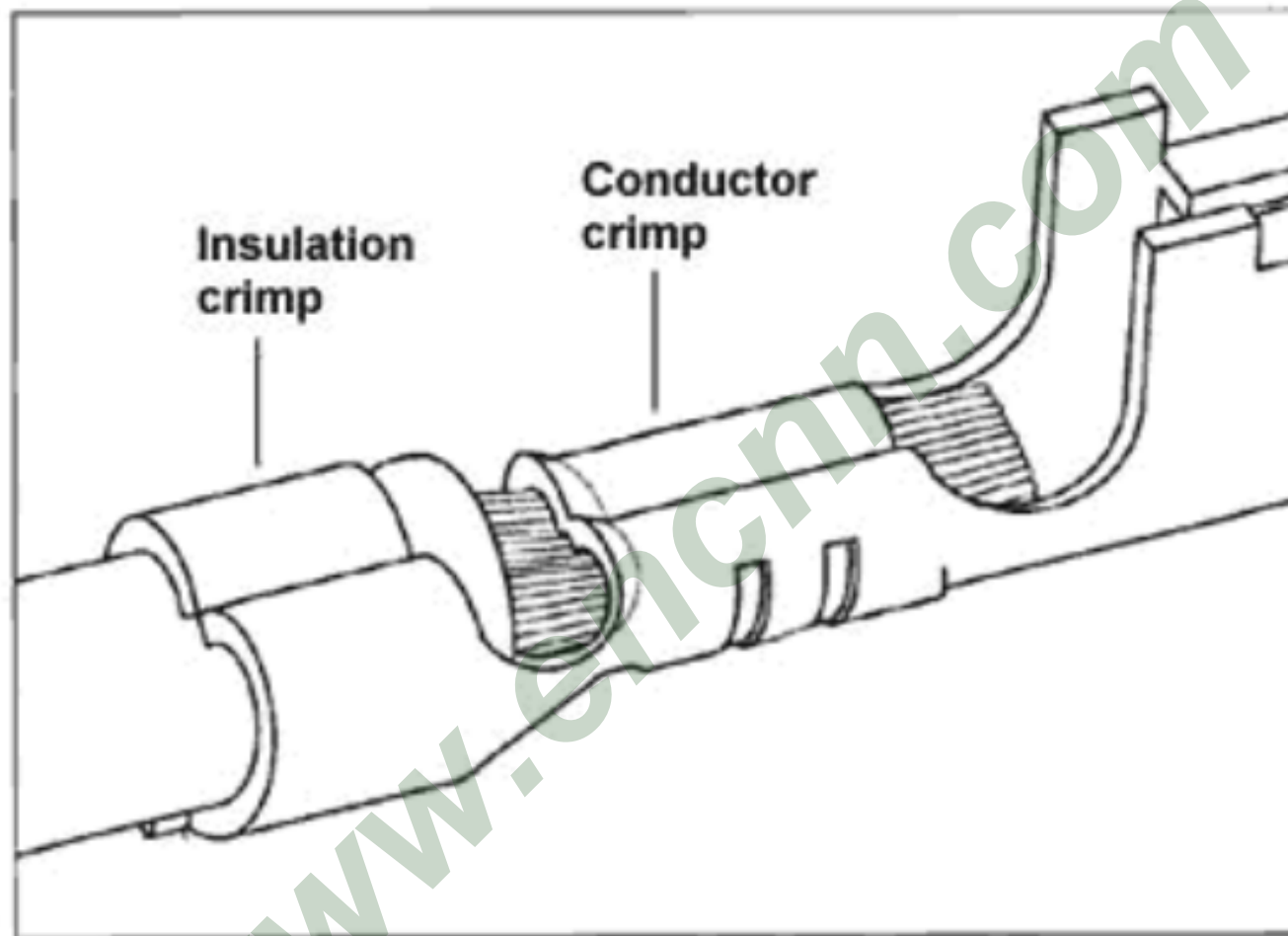
The diagram above shows wires in IDT slots. The wire on the right is partially stripped for illustration purposes. In actual application, insulation need not be removed, which is a major advantage of this method of termination.





Crimp 连接

Encnn



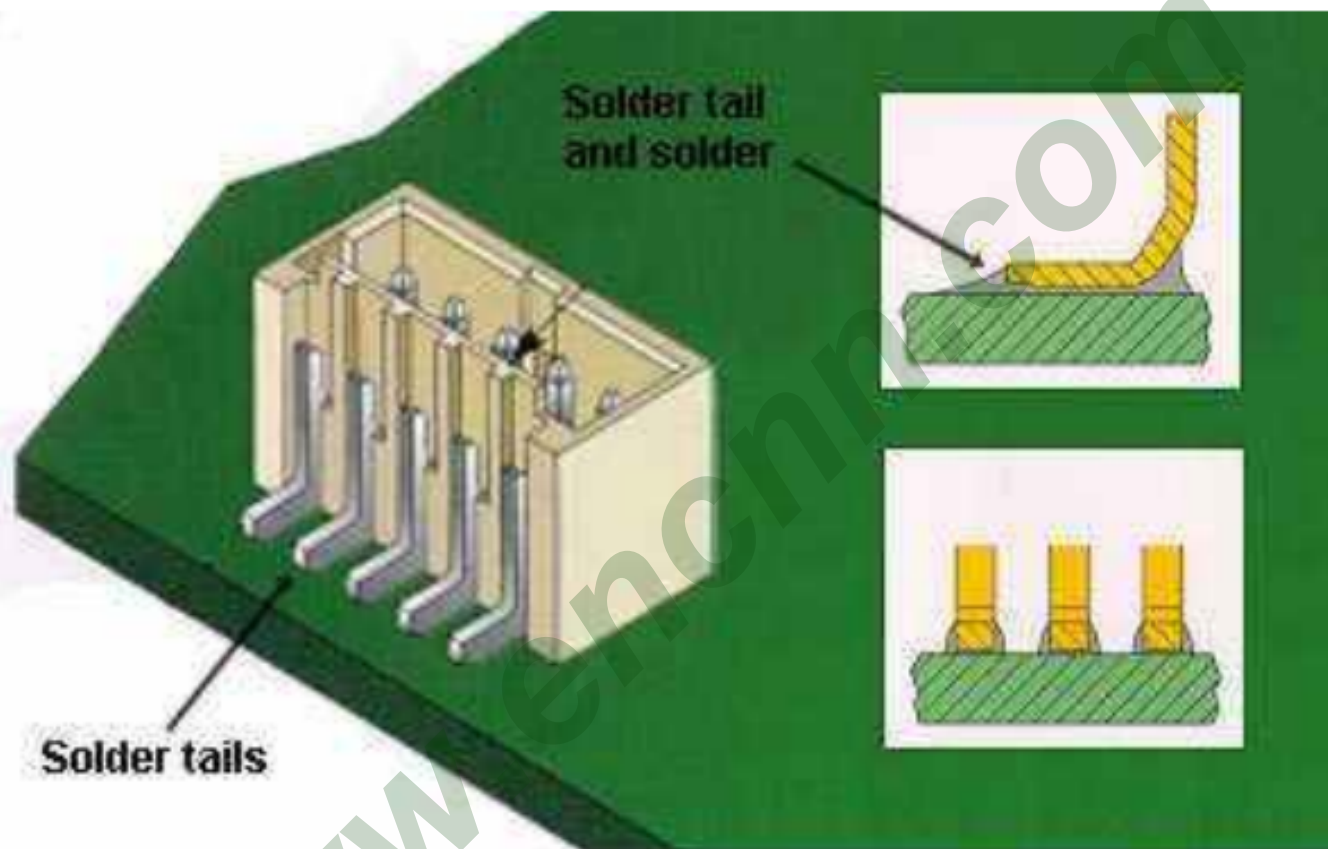
Note that the conductor is crimped in two places – on the wire and on its insulator. The latter is called a strain relief. It provides additional resistance to mechanical stress.

Encnn enables connection!
www.encnn.com



SMT连接

Encnn

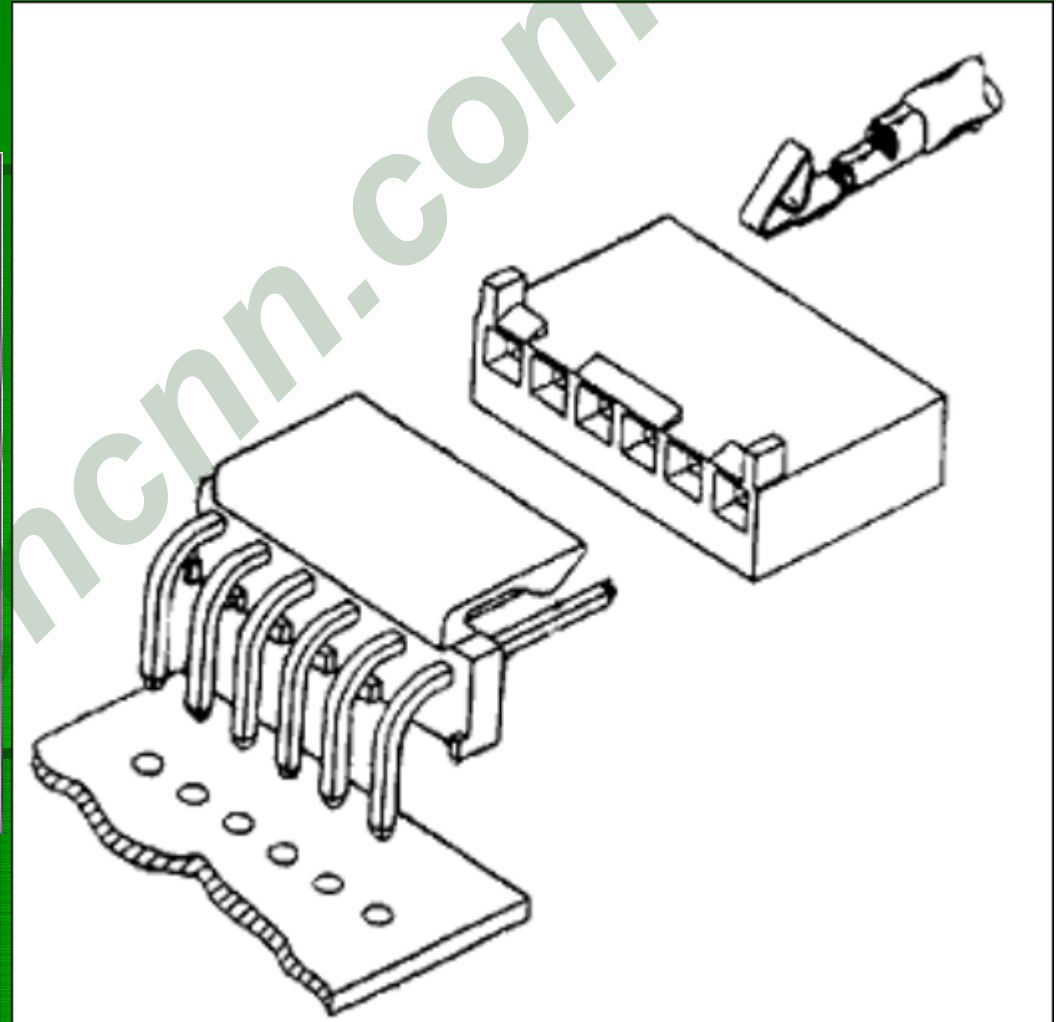
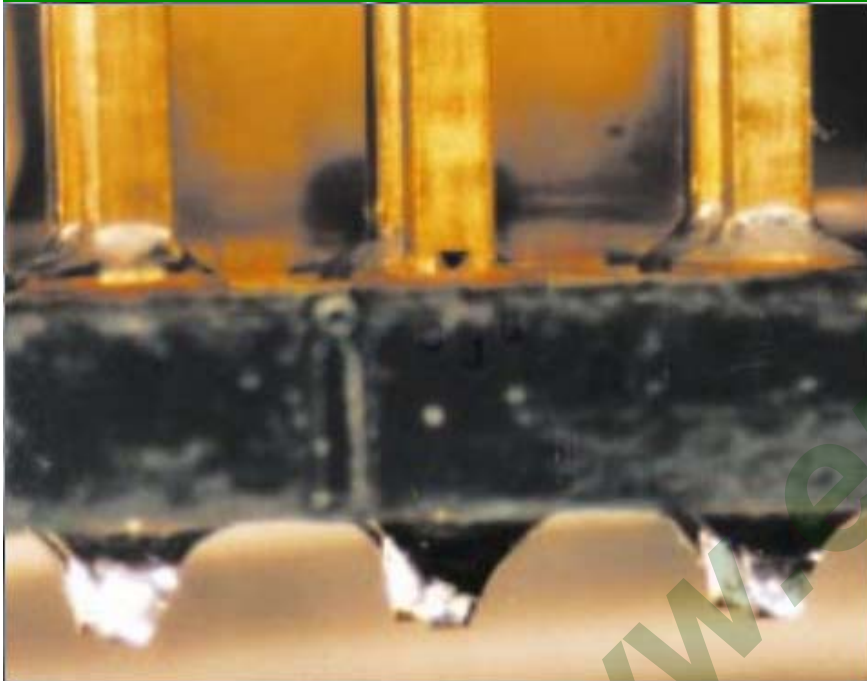


The SMT tails on this 1.50mm wire-to-board connector provide a large soldering area. Notice in the images on the right how solder is applied to all four sides of the tail. This assures maximum retention to the PCB, a quality called *shear strength*.

Encnn enables connection!
www.encnn.com



穿孔焊连接



Encnn enables connection!
www.encnn.com



电镀的规格及作用机理

- 两大类镀层：
 - 贵金属（Au, Pd及合金）
 - 非贵金属（Sn, Ni, Ag及合金）
- 镀层两大作用机理的区别：
 - 贵金属镀层自身不氧化/腐蚀
 - 非贵金属镀层自身可氧化/腐蚀
- 镀层不同作用机理对连接器设计(e. g. 正向力)的不同要求
- 不同镀层对连接器(性能)的影响：
 - 插拔次数
 - 接触电阻
 - 插拔力
 - 工作温度范围
 - 应用场合
 - 可靠性
 - 载流能力
 - 连接方式.

Encnn enables connection!

www.encnn.com



连接器弹片/端子

■弹片/端子的作用

- 从可分离界面向永久连接界面传递信号或能量
- 提供建立和保持可分离界面的正向力
- 为永久连接提供连接点及连接方式的组成部分

■弹片/端子导电和散热性能要求

■弹片/端子机械性能要求:

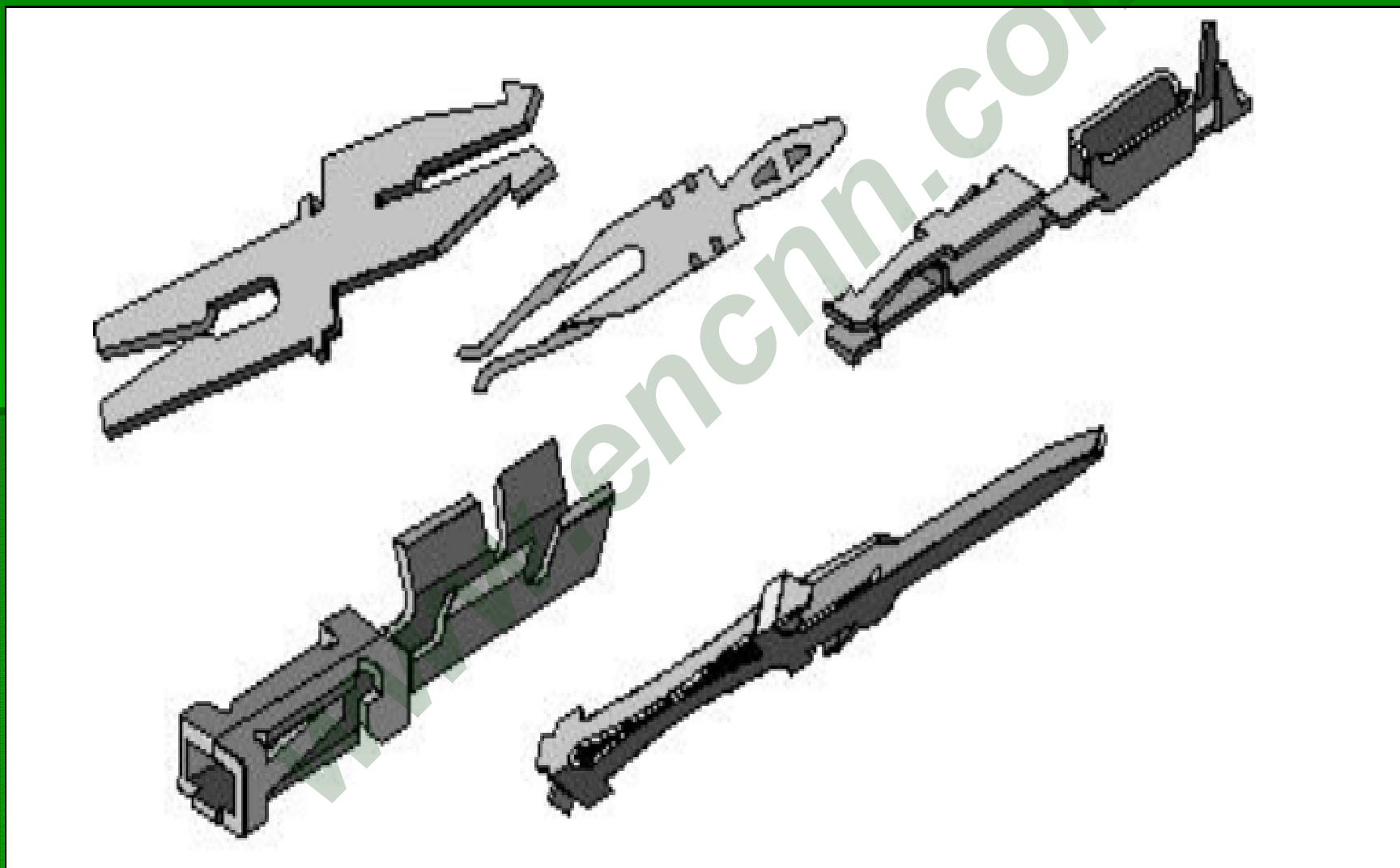
- 机械强度
- 加工工艺性/可成形性
- 可分离界面和永久连接界面的不同机械性能要求

■弹片端子的常见结构.



常见连接器弹片端子

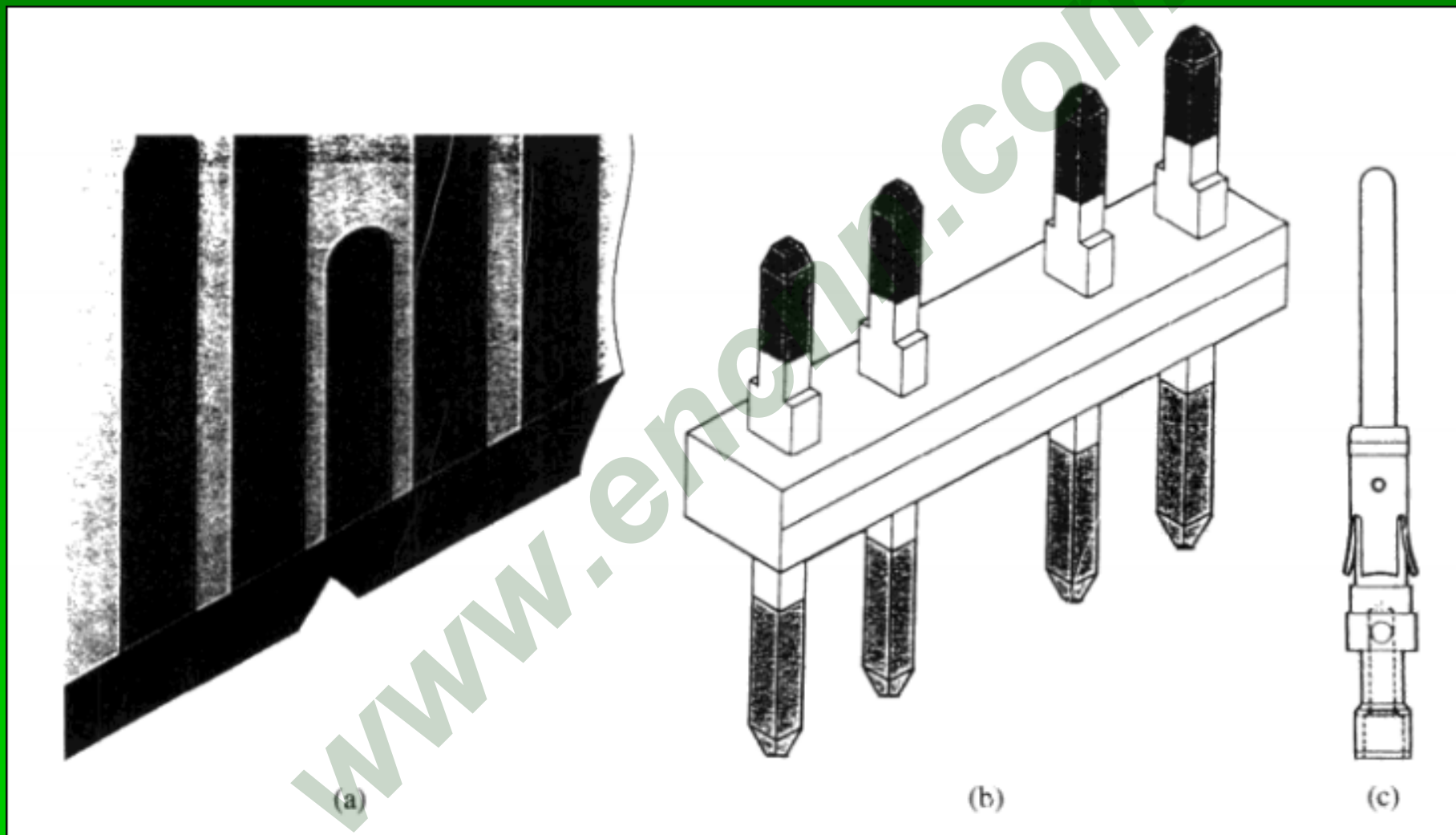
socket/receptacle





常见连接器弹片端子

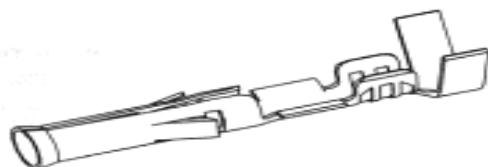
post/pin



Encnn enables connection!
www.encnn.com

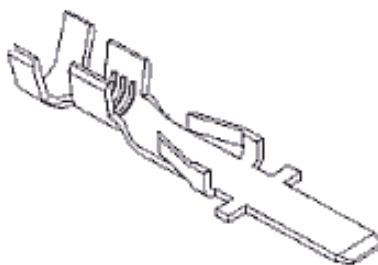


常见连接器弹片端子



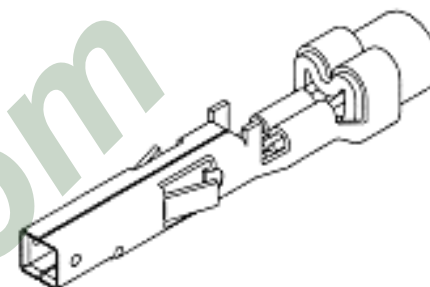
▲ PIN AND SOCKET

is our most common power terminal design for low current applications. It is used in .062", .093", .125" and MLX product families. The tubular shape provides multiple points of contact for an excellent electrical interface. Male and female terminals are interchangeable in plugs and receptacles. The male pin diameter indicates its size.



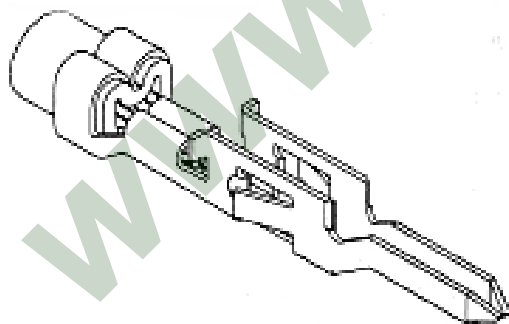
▲ BLADE TERMINALS

are used in our Sabre™ line. The terminal has a large flat surface for good strength and contact surface. It offers terminal position assurance (TPA) to prevent backout. Much thicker, wider blades are also used in our high-current products, to be shown later in this lesson.



▲ BOX TERMINALS

offer a mechanically strong interface with four points of contact. They are used in Micro-Fit, Mini-Fit, JR and HCS power products.



◀ U-SHAPED TERMINALS

offer four points of contact. They are found in our Mini-Fit, JR line, and are usually used for male terminals with a box female terminal.

Encnn enables connection!

www.encnn.com



连接器塑胶外壳

- 塑胶外壳的作用
 - 使连接器弹片/端子相互绝缘
 - 固定和保持弹片/端子位于正确的位置及维护连接器的形状
 - 为弹片端子提供支撑或保护
 - 隔离工作环境降低弹片端子受腐蚀的可能性或程度
- 塑胶外壳的性能要求：
 - 应用环境的要求
 - 注塑工艺性的要求
 - 组装工艺的要求（e. g. SMT耐高温要求）
 - 尺寸稳定性要求：直线度，平面度，位置度…
 - 电气性能要求：表面电阻系数，体电阻系数…
 - 机械性能要求：热变形温度，蠕变，杨氏模量…
 - 环境性能要求：耐候性，耐腐蚀性.



连接器测试

Type	Exposure	Measurement
Environmental	Mixed flowing gas Temperature/humidity Heat aging	Porosity T-rise Moisture absorption
Mechanical	Thermal shock Vibration Durability cycling	Pull strength Friction coefficient Mating force
Electrical	Overload current	Contact resistance

一项连接器测试一般由两部分组成：样品前处理和样品相关参数测量。前处理的内容决定连接器的测试类型。例如，将样品暴露在腐蚀性环境下一段时间（前处理），之后进行接触电阻测试（相关测试测量）。这种测试一般被认为是一种环境测试。连接器有三类测试类型：环境测试、机械性能测试、电气性能测试。见附表

Encnn enables connection!

www.encnn.com



连接器测试

连接器测试的基本原因是确认连接器的性能，除了**设计确认测试**（对模型或试产样品进行）——验证设计的有效性，大部分连接器测试是根据测试规范或**鉴定测试**程序确认连接器的性能，一般包含环境测试，机械性能测试，电气性能测试。测试的程序，测量和验收标准与连接器的应用场合和市场要求有关。针对一般应用场合和通用市场，测试的要求和验收标准也较通用。

当具体的应用环境成为测试程序的关注点时，测试的条件会更具体更准确反映实际的应用场合的状况，测量和验收标准也会如此。这被称为**性能确认测试**。

连接器**可靠性测试**类似于性能确认测试和鉴定测试，但也有两个明显的区别：第一点是可靠性测试必须清楚测试条件与应用场合的相互关系（这比鉴定测试要求严格很多）。换句话说，要求知道测试的加速因子，即测试中的A条件X天对应应用中的B状况Y年，这种要求不易满足也限制了可靠性测试的应用范围。第二点不同是验收标准——验收标准的范围和所需的统计处理。鉴定测试的验收标准是针对通用应用场合（产品允许的应用范围较广），即要求产品在各种常见的应用场合均能满足性能要求，故要求较高，验收的标准较严。所以可靠性测试的验收标准要宽松的多，但可靠性测试的统计要求严格的多的多，如抽样数量要大得多，统计分析要求更高。

Encnn enables connection!

www.encnn.com