

# Design for Testing - Impedance Controlled Boards 阻抗控制板的設計

Frontline PCB Solutions by: Ronny Kovartovsky

## Abstract

It is critical to constrain and control characteristic impedance on high-speed printed circuit boards. However, in most cases, space constraints do not allow for impedance test coupons to be placed on the actual part. This creates the need for external coupons to be placed on the panel, resulting in the consumption of production panel real estate and increased cost.

Placing impedance coupons across the panel, and not on the part, presents the manufacturer's engineer with a variety of coupon design challenges:

- A manual, time-consuming layout process that can take anything from minutes to hours to complete.
- An error-prone layout process, subject to design rule and signal integrity violations, (as engineers often try to make the design as compact as possible,) significantly increasing the challenge of manual layout.
- Requires expert work to make the coupons really efficient not only by packing more lines into the same impedance coupon, but by ensuring that they do not interfere with one another and do not add to the tooling cost.

This article describes a software solution that handles the above mentioned challenges to help front end departments in the PCB shop shorten the job editing cycle and optimize the quality of impedance coupon design.

## Why is Impedance Coupon Layout so Complicated?

Impedance coupon layout would be a very simple task if there were just one impedance line per coupon. This, however, is a very costly approach that reduces the amount of deliverable parts on the production panel, thereby increasing the production cost per unit.

## 摘要

在高速印刷電路板上，限制並控制特性阻抗至關重要。然而在很多情況下，空間的限制往往不允許將阻抗測試條(Impedance test coupon)放在PCB板內。因此就產生了將阻抗測試條放在PCB板外即工作排板(working panel)上，導致佔用工作排板的實際面積而增加材料成本。

將阻抗條放在工作排板上，而不是PCB板內，這給製造電路板的工程師們提出了許多關於阻抗條設計方面的難題：

- 手動、耗時的佈線需幾分鐘到幾小時才能完成。
- 手動佈線容易導致變更設計規則和信號的完整性（工程師們往往想盡辦法讓設計更加緊密），顯著提高了手動佈線的難度。
- 需要有精湛的技術才能設計出真正有效的阻抗條-不僅僅是將更多的線路群組在同一阻抗測試條中，還要確保線路之間互不幹擾，並且不增加工具成本。

本文介紹一個可以解決上述難題的軟體解決方案，幫助 PCB廠的製前部門縮短料號製作週期並優化阻抗條設計的品質。

## 為什麼阻抗條佈線如此複雜？

如果每個阻抗條上只有一根阻抗線，阻抗條佈線將是一件非常簡單的事情。但這種做法會減少生產的工作排板上出貨單元的數目，導致成本升高，從而增加了單位生產成本。

為了設計出更緊密的阻抗條，可以將多根阻抗線放在同一阻抗條上，這需要考慮設計規則和信號完整性方面的因素，以便在測試產品時得到高品質的信號。

設計時要考慮的細節為數眾多。下面略舉幾例：

- 並非所有的阻抗線都可以放在同一阻抗條上。判斷哪些阻抗線可以共用一個阻抗條是一項非常複雜的任務，這需要真正瞭解信號的工作原理，因而錯誤頻頻發生。
- 由於材料特性和製造方面的原因，設計要求的線寬與生產過程中的預計測量值並不完全相同。而

In order to create more compact coupon designs, where several impedance lines are placed on the same coupon, one needs to consider design rules and signal integrity factors so that product testing results in a clear signal.

There are many layout details to consider. Several of these are listed below:

- Not all impedance lines can be placed on the same coupon. Deciding which lines can share the same coupon is a complicated task that requires a true understanding of how signals work, and is therefore subject to frequent errors.
- Due to material properties and manufacturing issues, the line width required by the design is not exactly the same line width expected to be measured in production. However, this is the line that needs to be laid out on the coupon. The same complexity occurs with differential spacing that changes if differential line width is changed.
- A really compact design can be achieved by placing a few lines in a channel formed by each line of pads. And if coupon size is shorter than the required line length, the layout of the lines curves.
- Connectivity between layers is critical. Every line must be grounded through a drill to one of the adjacent ground layers. Manual coupon layout may require a very careful process to avoid connecting to the wrong ground layer or failing to connect some lines at all.
- Labelling Placing text in the right location with the right information, text size and orientation is another challenge that if done manually, may be time-consuming and become a major source of errors.

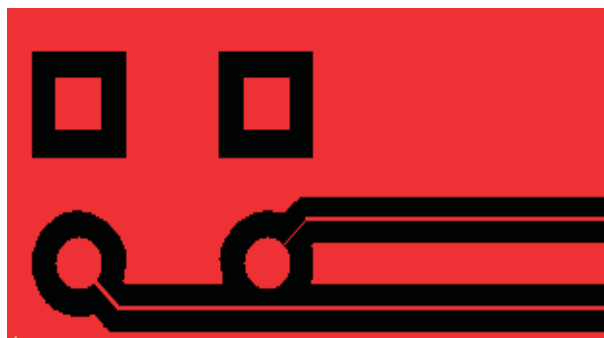
### Proposed Solution - Automatic Impedance Coupon Generation Software

Automatic Impedance Coupon Generation software should include the following major attributes in order to become a real solution to the challenges listed above:

- Support a range of pad layouts matching commonly used impedance-testing probes in the PCB industry.

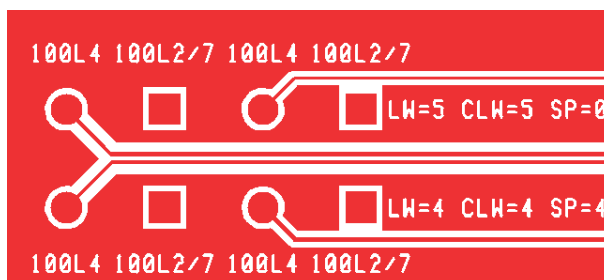
這種線路是需要設計在阻抗條上的。相同的複雜性還體現在差分線線距,隨差分線線寬的變化而變化上。

- 可以在一個通道中放置幾條接pad的線路，這樣可以實現真正緊湊的設計。如果阻抗條的長度小於阻抗測試線長度，則需要以曲線佈線。



Two lines in the same row

- 層與層之間的導通非常關鍵。每條線都必須通過鑽孔接地到一個相鄰的接地層。手動設計阻抗條則需要非常小心以避免將線路連接到錯誤的接地層或根本沒有接上。
- 標記 在阻抗條上適當的位置加上正確的阻抗資訊、合適的文字大小和文字方向，這對手動操作來說是另一個挑戰，不僅會非常耗時並成為主要的錯誤來源。



Readable text is a challenge  
文字添加是一個挑戰

### 推薦的解決方案 阻抗條自動生成軟體

阻抗條自動生成軟體必須具備以下幾大特徵才能成為應對上述難題的解決方案：

- 支援多種Pad 佈線，適合 PCB 行業中常用的阻抗測試探針。

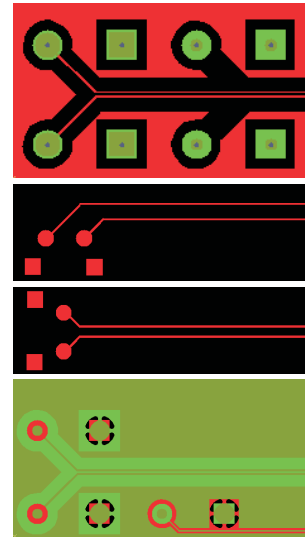


- Automatically group impedance lines to reduce the amount of coupons and minimize the coupon footprint on the panel.
- Compact Layout to minimize the coupon footprint on the panel while still maintaining all design, manufacturing and signal integrity rules. Coupon sizes may be determined by the remaining space on the panel, so that long impedance lines are packed into a relatively short coupon. The software should be able to handle these scenarios.
- Automatic labelling - To provide clear readings on the coupon during testing.
- Sub-assembly testing - To design impedance coupons that can be tested at earlier production stages in order to reduce the cost of malfunctioning boards as early as possible. This advanced capability requires an understanding of the PCB buildup as well as the sub-assembly structure of the board.

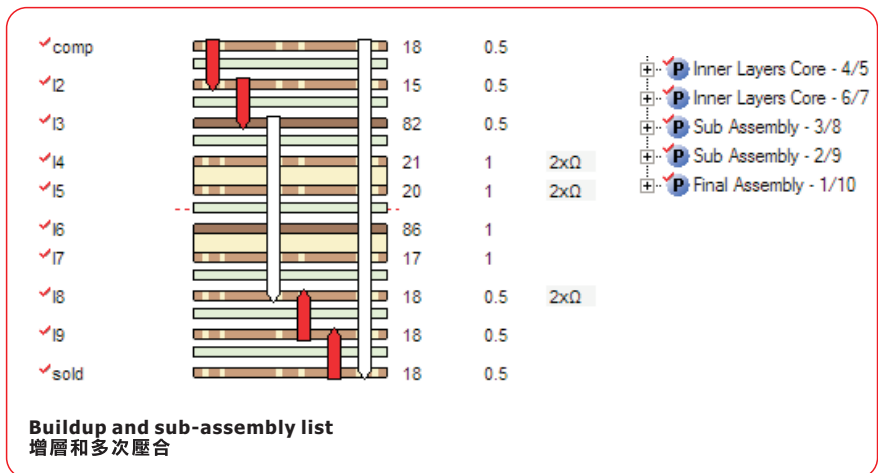
Impedance coupons should be automatically designed for high yield and cost-effective manufacturing. Coupons should meet all design and manufacturing rules and should use the same tooling cycles and tooling sets already in use for manufacturing the deliverable part.

- Flexible shielding capabilities - The software should allow users to configure a variety of shielding patterns in impedance coupon trace layers, including solid, dots and guard trace patterns.
- Integration with the most popular stackup design, engineering and CAM systems. This information is essential for determining the interconnectivity between coupon layers. Integration with CAM will enable the seamless transfer of impedance coupon data to the CAM system to ensure the coupons are successfully added to the production panel. Integration with engineering systems is also crucial, since in many cases, shop floor documentation requires

- 自動對阻抗線進行分組，從而減少阻抗條的數量並使阻抗條在工作排板上佔用的空間最小。
- 緊密的佈線，使阻抗條在工作排板上佔用的空間最小，又不違反所有設計、製造和信號完整性規則。阻抗條的大小可由工作排板上的剩餘空間決定，因此較長的阻抗線可設計到相對較短的阻抗條中。這軟體應能夠解決這些情況。
- 自動標記 - 可以提供阻抗測試時所需的清晰可讀的文字。
- 多次壓合測試 - 設計在多次壓合生產階段測試的阻抗條，以便儘早發現有故障的電路板以降低製造成本。這一先進的功能的測試必須充分瞭解 PCB 增層以及電路板的多次壓合原理。



**Long Impedance lines packed into a relatively short coupon**  
較長的阻抗線 設計到相對較短的阻抗條中

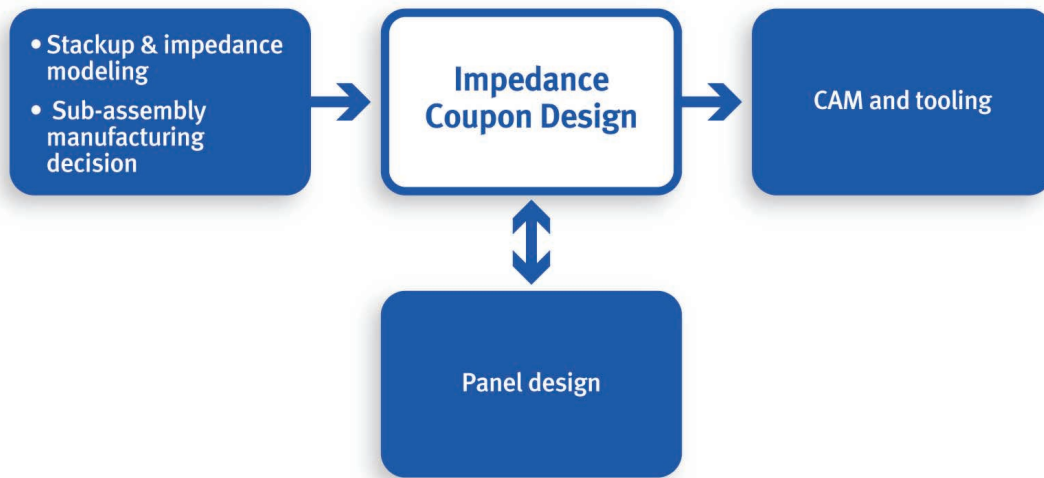


自動設計阻抗條，以實現高良率和經濟有效的製造為目的。阻抗條應符合所有設計和製造規則，並使用目前已用於製造出貨單元的相同加工週期及設備。

- 靈活的護衛銅功能 - 軟體應允許用戶在阻抗條線路層中配置多種護衛銅圖形，包括實線、點線和防護線圖案。
- 與最流行的堆疊設計、工程和 CAM 系統整合。此資訊對確定阻抗條層之間的互連性至關重要。與 CAM 整合可以將阻抗條資料無縫傳送到 CAM

a graphical description of the impedance coupon. In the top class of engineering systems available today, there are also robust panel design tools that take impedance coupon sizes and quantities into consideration in their panel layout optimization program - thus ensuring better utilization of the panel area.

系統，以確保將阻抗條成功添加到工作排板上。與工程系統的整合同樣重要，因為在多數情況下，現場的文檔需要以圖形方式對阻抗條進行描述。在當今頂級的工程系統中，還有一些功能強大的排版設計工具能夠在進行優化排版時同時考慮阻抗條的尺寸和數量，從而提高材料的利用率。



## Conclusion

Impedance coupon design is a time-consuming preproduction challenge that requires expert understanding of impedance modelling, signal integrity and manufacturing processes.

Automatic, integrated Impedance Coupon Generation software may be considered as a solution to the challenges described above, and delivers the following benefits:

- Reduces CAM and Engineering cycle time.
- Generates coupons that meet all DRC, signal integrity and testability requirements.
- Designs coupons for impedance testing in the early production stages.
- Minimizes the coupon footprint on the panel leaving more space for sold footage.
- Transforms coupon design from an expert task to a standard operation.

## 結論

阻抗條設計是一道非常耗時的製前工序，需要透徹瞭解阻抗模型、信號完整性和製造流程。

自動、整合的阻抗條產生軟體是解決上述難題的理想之選，它具有以下優點：

- 縮短 CAM 和工程週期
- 生成能滿足所有 DRC、信號完整性和可測試性要求的阻抗條
- 在多次壓合生產階段就能進行阻抗測試的阻抗條
- 最大限度減小阻抗條在工作排板上佔用的面積，從而留下更多的空間留給需出貨的單元。
- 使阻抗條設計從專業演變為標準作業