Appnotes

Designing Balanced Printed Circuit Boards

Benefits of balanced designs

Balancing layer counts to avoid warp

Modifying designs to achieve even layer counts

Designers can be tempted to design printed circuit boards (PCBs) with an odd number of layers. If the additional layer is not needed for routing, why use it? Won't eliminating the extra layer minimize board thickness? If the board has one less layer, the cost should be lower...shouldn't it? But, on occasion, *adding* a layer can help reduce costs.

The stackup of layers in the board can be handled in two different ways: core construction or foil construction (*See Figure 1*).

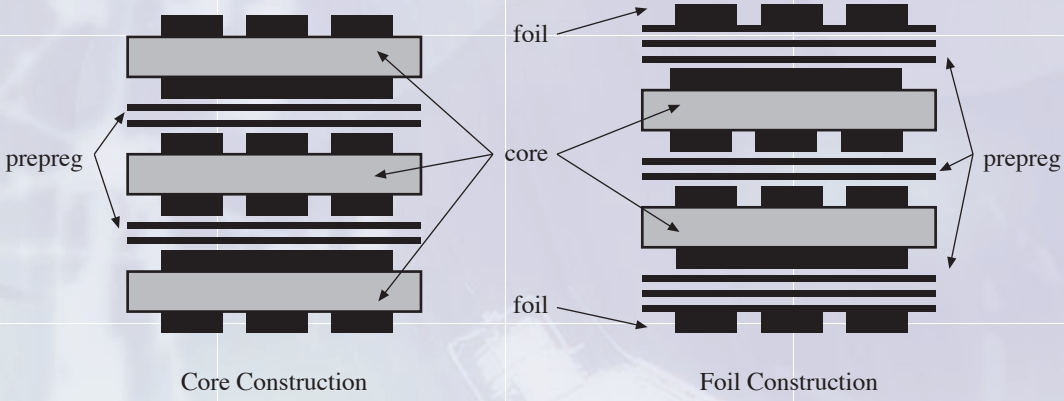

Figure 1 -
Core vs Foil Construction

Core construction attaches the conductive layers of the board to a core material. Foil construction attaches all conductive layers except the external layers to a core material. The external conductive layers of the board for foil construction are added using sheets of copper foil.
All of the layers are bonded together using a prepreg at the multilayer lamination process.

Core materials come to the PCB fabricator with copper laminated on both sides. Since each core has two sides, the total number of conductive layers should be an even number to fully utilize the material. Why not use foil on one side and core on the other? The primary reasons are cost and warp.

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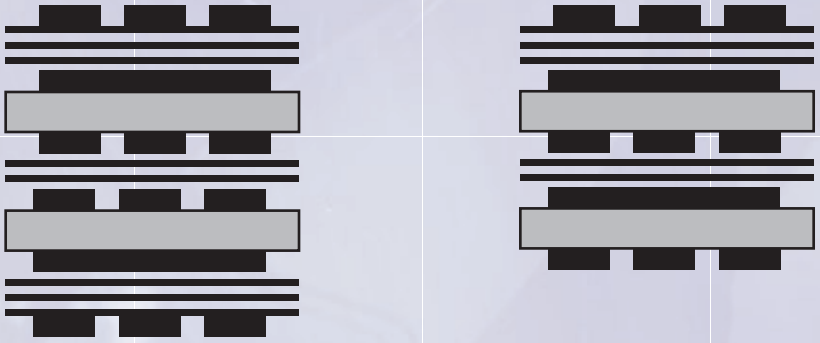
Cost Advantages of Even Layer Count Boards

The cost of the *raw materials* is slightly less for a PCB with an odd number of layers than for a PCB with an additional layer, due to the prepreg and foil for the additional layer. However, the *processing costs* can be significantly higher for an odd layer count board with foil on one side and core on the other. The inner layer processing costs are identical, but the foil/core construction dictates additional processing costs for the external layers (*See Figure 2*).



Foil Construction (even # layers)

Foil / Core Construction (odd # layers)

Figure 2 -
Foil Construction vs
Foil / Core Construction

The odd layer count board incurs additional cost for a non-standard layup process and additional pressing materials like those used for a core construction board. The manufacturing yields are also lower for boards with a core instead of foil on the external layers. The external core requires additional processing prior to lamination, and is subject to increased risk of handling damage like scratches or voids etched into the copper.

Balancing Layer Counts to Avoid Warp

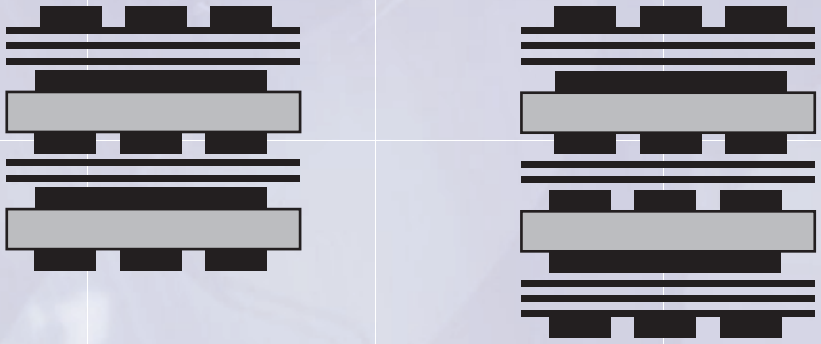
The best reason to avoid designing a board with core on one side and foil on the other is the potential warping of the PCB. As the board cools after multilayer lamination, it can warp to relieve the different lamination stresses on the foil side and the core side. Boards constructed with core on one side and foil on the other have a very high risk of warp, especially as board thickness increases. The key to eliminating warp is to create a balanced stackup.

Although some warped boards can meet specifications, the cost of processing them increases because inefficient processes are used to continue manufacturing a warped board. Quality is compromised because these boards require special fixtures and processes for assembly, and component placement is less accurate.

Modifying Designs to Achieve Even Layer Counts

When a design appears to require an odd number of layers, several methods are available to balance the layup and avoid significant processing costs and warp problems. In order of preference, the following methods can yield more balanced boards:

1. Add an additional signal layer and use it (*See Figure 3*). This method is generally applied to boards with an even number of planes and an odd number of signals. The additional layer does not add to the cost of the board, and it can improve delivery and quality.

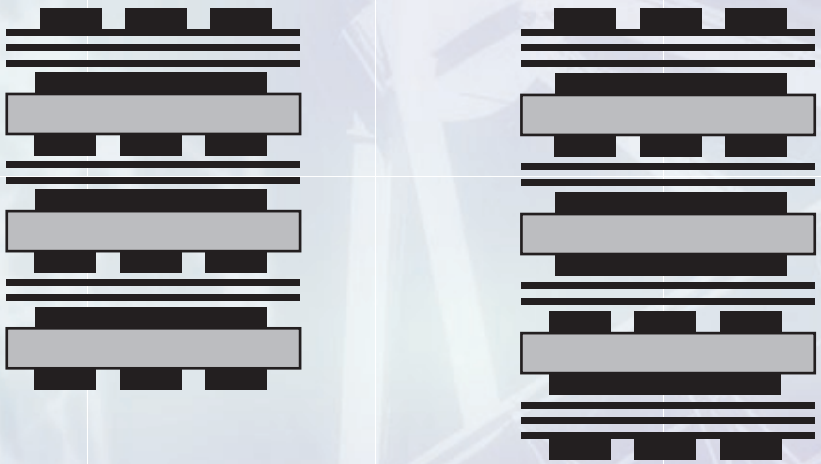


Odd Layer Stackup Even Layer Stackup

Figure 3 - Add signal layer

2. Add an additional plane layer. This method is generally applied to boards with an odd number of planes and an even number of signals.

   An easy way to create a balanced layup without compromising the electrical requirements of the board is to duplicate a ground plane in the center of the stackup. Route the board with the odd number of layers, then duplicate the ground in the center of the board and relabel the remaining layers. This has the same electrical effect as using thicker copper for the ground plane.

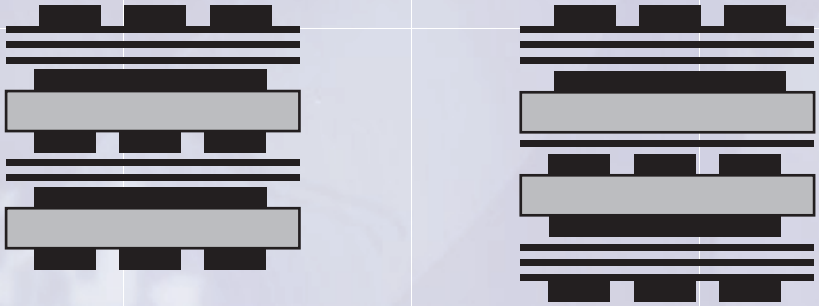


Odd Layer Stackup Even Layer Stackup

Figure 4 - Add plane layer

3. Add a blank signal layer near the center of the stackup. This minimizes the imbalance and gains the quality and processing benefits of a foil construction board. Route the board with the odd number of layers, then create a blank layer with no circuitry as a signal layer and relabel the remaining layers.

   Adding a blank signal layer also works with microwave boards and other mixed dielectric boards where prepregs have different electrical properties than the core material.



Odd Layer Stackup

Balanced Odd Layer Stackup

Figure 5 -
Add blank signal layer

Benefits of Balanced Designs

PCBs with an even number of layers minimize cost, warp, delivery, and quality issues. By using the options presented in this note, a board designed with an odd number of layers can be modified to balance the stackup and minimize the risks associated with an odd number of layers. If the specific design cannot be constructed using the techniques presented in this note, please contact Merix' Application Engineering group as early as possible in the design process.