Royal Circuit Solutions
21 Hamilton Ct, Hollister, CA 95023

(831) 636-7728
www.RoyalCircuits.com

FABRICATING HIGH CURRENT, HEAVY COPPER PCBS

INTRODUCTION

All printed circuit boards (PCBs) carry current through copper traces and planes etched on to the different layers. Defined primarily by economics and circuit density, increasing the width of a copper trace to accommodate a higher current is not always an option available to designers. A solution to the above dilemna lies in increasing the thickness of the copper trace, without altering its width. The result is a heavy copper PCB, capable of carrying high currents and conducting heat away more efficiently.

Although there are no set rules defining the copper thickness to set a heavy copper PCB apart from the regular ones, the industry has a thumb rule—3 or more ounces of copper on any layer classifies the PCB as a heavy copper type. There is no upper limit to the copper thickness, as one can find PCBs with inner layers as thick as 8 Oz, and outer layers up to 40 Oz thick. Several industries use heavy copper PCBs, for applications involving power amplifier modules, DC-to-DC power converters, planar transformers, heat dissipation products, automotive power distribution junction boxes, high power distribution boards, and many more that make use of high currents. Compared to conventional printed circuit boards, a PCB with heavy copper traces and/or planes offers several advantages:

A SIMPLE & STRONG STRUCTURE

High current circuits, when integrated into the PCB allow designers achieve higher density and reduce the layer count. This also keeps the structure of the PCB relatively strong but uncomplicated.

REDUCES FAILURE RATES

Complex printed circuit boards with high current requirements generate more heat. Copper has high heat conducting abilities and helps to conduct heat away from vital temperature-sensitive components.

LOWERS PRODUCTION COSTS

Although copper is expensive, rather than use copper cables, using PCBs with heavy copper result in overall lowering of production costs.

DESIGN CONSIDERATIONS

Electronic design engineers decide the amount of required current. They then design the heavy copper PCB capable of carrying that current. This requires determining the copperthickness, its width, and the maximum temperature rise the PCB can withstand—the heat a heavy copper PCB generates is closely related with the current it is carrying during operation.

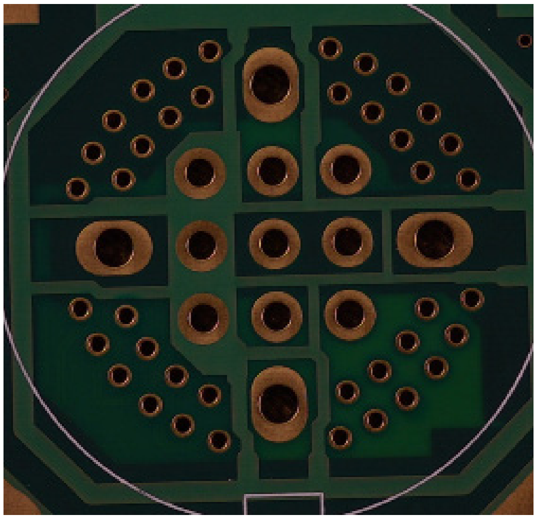
As current passes through a copper track, its resistance causes the track to become hot. The power thus generated is a local heat transition that has to dissipate into the surroundings by way of conduction and convection. The designer must calculate the maximum current the trace on a heavy copper PCB can carry before it reaches the acceptable temperature rise of about 30°C. A thumb rule in the industry is the inner layers can cope with only 50% of the current carrying capacity of the exposed traces.

The substrate material of the PCB is another factor the designer must consider when designing heavy copper PCBs. Substrate materials extend from ordinary FR-4 material with operational temperatures of 130°C to improved materials with very high glass transition temperatures (Tg).

Thermal coefficient of expansion (TCE) between copper and the substrate material is also a driving force, as thermal stresses generated by high currents through traces may lead to creation of cracks and layer separation, finally driving the PCB to failure.

REDUCING COPPER RESISTANCE

Fabricators can thicken the surface of circuit boards through electroplating. This process of additive plating reduces the resistance of copper traces, thereby improving the heat conducting property of the board surface. Fabricators apply this process to thickening the thermal PTH copper plating as well, successfully reducing its thermal resistance.



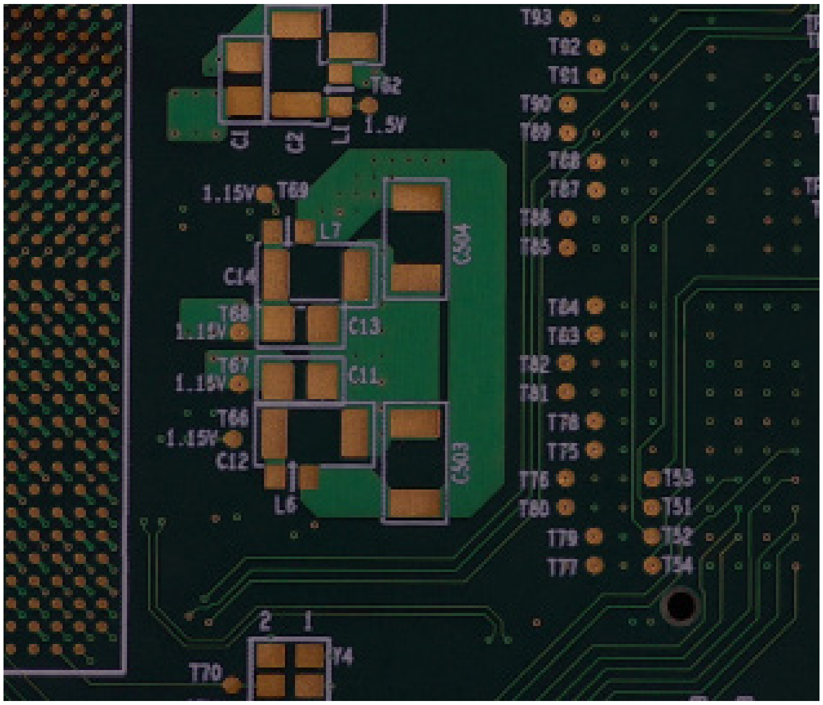
Reduction in the copper resistance helps in dissipating heat more effectively through thermal conduction, convection, and radiation.

FABRICATING HEAVY COPPER PCBS

Fabricating methods for heavy copper PCBs do not differ much from standard FR-4 PCBs. However, they do require special etching and plating techniques to suit the extra thickness of copper, including high-speed plating and deviation etching.

Manufacturing with normal etching methods do not work for heavy copper, as they tend to produce uneven edge lines and over-etched margins. Fabricators have evolved advanced plating and etching techniques to obtain straight edges and optimally etched margins.

Fabricators also electroplate heavy copper PCBs to thicken the walls of plated through holes (PTH) on the PCB. This offers several advantages such as shrinking the layer count, reducing impedance distribution, reducing package size, and lowering manufacturing costs.



However, designers need to discuss with their fabricators the thickness, spacing, and tolerances they require on heavy copper PCBs and the feasibility of fabricating such boards.

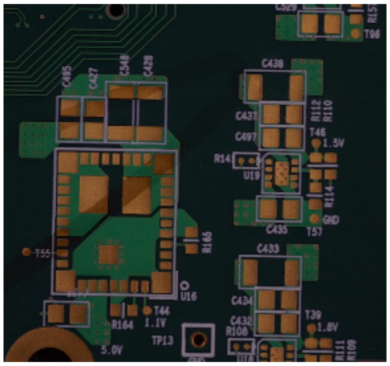
Fabricating thick copper PCBs involves some limitations:

- The etching process is difficult—causes low throughput and pushes up the cost
- Huge amounts of copper need to be removed during the etching process
- Lamination process requires the use of prepreg with high resin content to fill in spaces between the heavy copper traces
- Heavy copper traces on the outer layers makes the surface uneven and it is difficult to print solder mask and legend on the uneven surfaces
- Coexisting thick copper traces and finer lines for digital control is difficult to fabricate

BLUE BAR METHOD

Manufacturers adopt different methods for fabricating PCBs with heavy and normal copper traces on the same layer. For instance, for automotive PCBs, fabricators use the bus bar method. The process involves embedding thick copper bars into PCBs for carrying the extra current. As high power circuits need to use thick copper only for a few traces that carry high current, the bus bar technique saves material and reduces PCB weight. While fabricating, resin usually flows into the space between the thick copper traces, making the top surface even. With high power components sitting on the opposite side of the bus bars and thermally connected to them through thermal vias, the bus bars play an additional role of heat sink.

For multilayer PCBs using heavy copper layers, fabricators must pay particular attention to the copper fill level between inner layers. Low fill levels and low resin levels may result in resin hunger, which creates voids between the layers of a PCB, resulting in delamination.

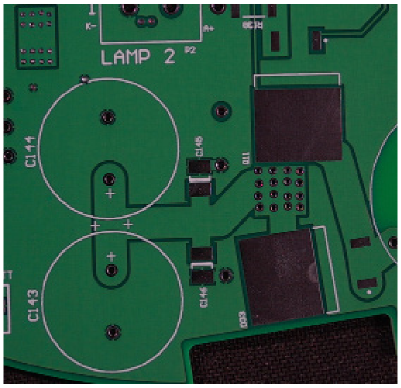


EMBEDDED COPPER METHOD

This technique creates a heavy copper PCB with a flat surface, with the heavy copper embedded within the prepreg res-in. The thickness of the heavy copper is limited to the thickness of the resin.

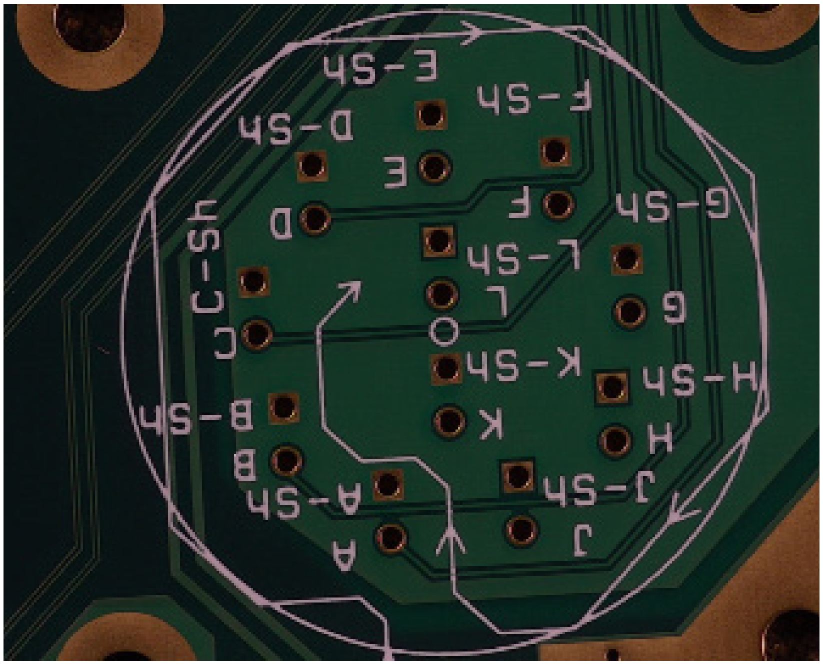
The fabricator starts with say, a 6-mil thick single side laminate with a 1 Oz copper clad. He covers the copper clad with a photoresist and uses a 5-mil wide laser beam to cut the circuit pattern from the laminate side. The laser needs to cut through the laminate up to the copper foil, exposing it. By controlling the laser, it is possible to prevent damage to the copper foil. If the laser is of CO_2 type, a de-smear process step may be necessary to remove the resin residue on the copper foil.

The fabricator then places the laser cut laminate into a plating tank for electroplating. The copper plating ultimately fills the laser cut groove on the laminate, producing a plating thickness of about 6 mil.



In the next step, the fabricator removes the photoresist. The plated laminate can now function as an inner layer core or as an outer layer. If necessary, the fabricator can etch the top side copper foil cladding to the circuit pattern. Together with the plated copper, the 1 Oz copper foil with have an additional 6 mil electroplated copper behind it, to form a total copper thickness of over 5 Oz.

If the etching process removes copper only from the thin section and none from the copper cladding backed by the electroplating, both thick and thin copper are present on the same layer, with most of the heavy copper buried within the laminate. Moreover, the top surfaces of the thin and thick copper are on the same level without any height differences. There is also no need to worry about peel strength, even though thin traces run beside the thick ones.



CONCLUSION

With the increase in demand for heavy copper PCBs, fabricators are developing newer methods of incorporating heavy copper with standard features on the same PCB. This lowers the layer count, offers low impedance for power distribution, enables smaller footprints, and offers cost savings. Electroplating helps to integrate heavy copper for high current circuits and regular copper for control circuits allowing designers and fabricators realize high density but simple board structures.

FREE CONSULTATION

Contact us to schedule a free consultation with a PCB engineer to learn more about heavy copper PCBs: www.royalcircuits.com or 1-831-636-7789.