Sheet resistance of copper foil: Rule of Thumb #13

Eric Bogatin - June 19, 2014

This rule of thumb is the most important DC resistance figure of merit about copper foil used in a printed circuit board.

Spoiler summary: The sheet resistance of 1oz copper foil is about 0.5mΩ per square.

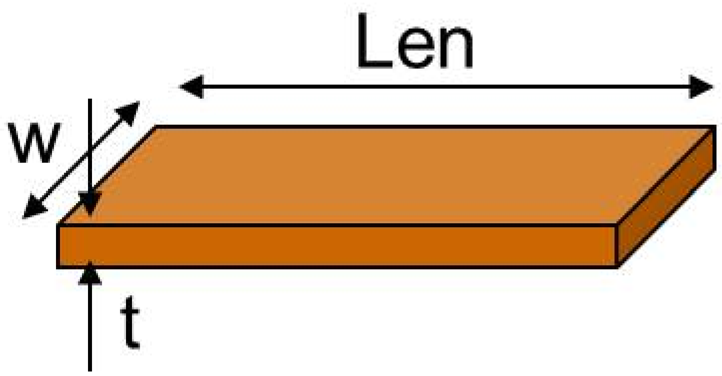
Remember: before you start using rules of thumb, be sure to read the Rule of Thumb #0: Use rules of thumb wisely.

Previous: Rule of Thumb #12: How much return loss is too much?

With all the talk these days of high speed this and gigabit that, it's easy to forget that DC is still important as well. With a V_{DD} supply of 1V typical in many 45nm devices today, and power dissipation running to 100W or more in CPUs and GPUs, there's more than 100A of DC current needed to feed these hungry beasts.

If there is even 1mΩ of DC resistance in the path, this will cause 100mV of IR drop, usually a disaster in 1V rails. Being able to estimate the DC resistance of a path is the first step in controlling it, and having confidence in a design.

This rule of thumb calculates the most important figure of merit about the DC resistance of copper sheets in circuit boards. The starting place is the basic calculation of the series resistance of a rectangular trace, as shown below:



The resistance from one narrow edge of the copper trace to the opposite edge, assuming uniform current through the trace, is simply given by:

$$R = \rho \frac{Len}{w \times t} = \left(\frac{\rho}{t}\right) \times \left(\frac{Len}{w}\right)$$

Where:

R = the resistance from one end to the other end of the copper trace

r = the bulk resistivity of copper, usually in units of µΩ•cm

Len = the length of the trace

w = the width of the trace

t = the thickness of the copper foil.

In one layer of copper foil, every trace will have the same value of bulk resistivity and conductor thickness. I rewrote the equation slightly to separate the resistance into two terms. It highlights a very simple pattern.

Let's take a look at a very specially shaped trace in the shape of a square, so the length equals the width – the ratio of length to width is 1. If we double the length of the trace, the series resistance will double. If we double the width, we increase the cross section for current to travel, and the resistance will be cut in half. If we do both, the ratio stays the same, and the edge-to-edge resistance stays the same.

The edge-to-edge series resistance of any square cut out of the same sheet of copper foil is just the bulk resistivity divided by the sheet thickness. We give this the special name of the "sheet resistance" or "the resistance per square":

$$R_{sq} = \left(\frac{\rho}{t}\right)$$

This is the most important figure of merit that describes the resistive properties of a foil.

We measure the thickness of copper foils by the weight per square foot. For example, 1oz copper foil has a weight of one ounce per square foot. The thickness of 1oz copper foil is about 34µm, or 1.4 mils.

The IPC spec for copper bulk resistivity at 20ºC is 1.72µΩ•cm. This makes the sheet resistance of 1oz copper foil about:

$$R_{sq} = \left(\frac{\rho}{t}\right) = \left(\frac{1.72 \times 10^{-6}\Omega \bullet cm}{0.0034cm}\right) = 0.5m\Omega / sq$$

This is the origin of the very simple rule of thumb that:

> *The sheet resistance of 1 oz copper foil is 0.5mΩ/square. And the sheet resistance will scale inversely with the geometrical thickness.*

Now you try it:

1. what is the sheet resistance of ½ oz copper foil?
2. what is the sheet resistance of 2 oz copper foil?

Next rule of thumb #14: Estimating trace resistance from sheet resistance and number of squares.

Also see:

- Improve PCB layout with power integrity analysis