Counting squares: A method to quickly estimate PWB trace resistance

Vincent Spataro -April 12, 2013

Introduction

We often have a need to quickly estimate the resistance of a printed wire board trace or plane without resorting to a lengthy calculation. Although printed circuit board layout and signal integrity computer programs exist that can accurately compute trace resistance, we sometimes want to be able to make a fast rough estimate as part of the design process.

A method that allows us to accomplish this with very little effort is called "counting squares." Using this method, we can make accurate (within 10% or so) estimates of any trace geometry in just seconds. Once you understand the method, you simply divide the printed wire board area that you want to estimate into squares and then count all the squares to estimate your total trace or plane resistance.

The Basic Concept

The key concept in counting squares is that any size square of printed wire board trace (of a given thickness) has the same resistance as any other size square. The resistance of the square depends only upon the resistivity of the conducting material and the thickness.

We can use this concept on any type of conducting material. Table 1 shows a number of common conductors, along with their bulk resistivity.

Metal	Bulk Resistivity [μΩ-in]
Aluminum	1.11
Copper	0.665
Gold	0.866
Molybdenum	2.24
Silver	0.642
Tungsten	2.13

Table 1: Bulk Resistivity of Common Metals Used for Electrical Interconnects

For printed circuit boards, the most important material is copper, which is used to fabricate most circuit boards. (Note that aluminum is used to metalize integrated circuit die, and these principles apply there, too.)

Let's start by looking at the square of copper represented by Figure 1.

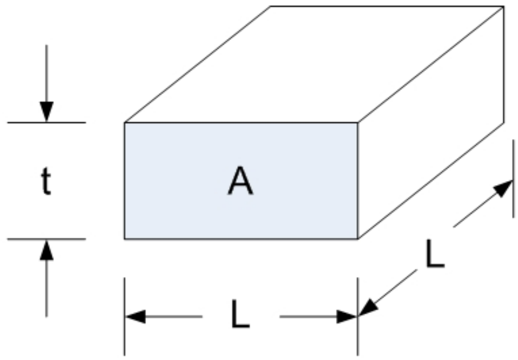

Figure 1: A Representative Square of Copper

The copper has a length (L), and because it is a square, a width (L). It has a thickness (t), and the current flows through the cross sectional area of copper (A). The resistance of this copper square is simply:

$\boldsymbol{R} = \rho L / A$

where ρL is the resistivity of the copper (an intrinsic property of the material – 0.67µΩ-in. at 25°C). But notice that the cross section A is just the length (L) times the thickness (t). The result is that the L in the numerator is cancelled by the L in the denominator, leaving:

$\boldsymbol{R} = \rho / t$

Hence, the resistance of the copper is independent of the square's size that we measure. It just depends upon the resistivity of the material and the thickness.

If we know the resistance of any size square of copper and if we can break up the entire trace that we want to estimate into a number of squares, then we can simply add up (count) the number of squares to find the total resistance of the trace!

Implementation

To implement this technique, we need only a table showing the resistance of a square of printed wire board trace as a function of the thickness of our copper. Copper thickness is commonly specified by copper weight (e.g., 1oz., 2oz., etc.). For instance, 1oz. copper weighs 1oz. per square foot.

The table below shows four of the most commonly used copper weights and the resistivity of each at 25°C and 100°C. Note that the copper resistance increases with increasing temperature, owing to the positive temperature coefficient of the material.

Cu Weight oz.	Thickness mm(mils)	mΩ/Square 25°C	mΩ/Square 100°C
1/2	.02 (0.7)	1.0	1.3
1	.04 (1.4)	0.5	0.65
2	.07 (2.8)	0.25	0.36
4	.13 (5.3)	0.13	0.18

Table 2: Copper Resistance versus Copper Weight

We now know, for example, that a square of ½ oz. copper has a resistance of about 1 mΩ. This is regardless of the size of the square. If we can break up the printed wire board trace that we want to measure into imaginary squares, then adding up all the squares in series will give us the resistance of the trace.

A Simple Example

Let's take a somewhat trivial example. Figure 2 shows a rectangular trace of copper, which we will assume to be ½ oz. weight at 25°C. The trace is 1 inch wide and 12 inches long. We can divide this trace into a series of squares, each 1 inch on a side. There would be twelve squares altogether. Since each square of ½ oz. copper is 1 mΩ according to our table, and we have twelve squares in series, the total resistance of the trace is 12 mΩ.

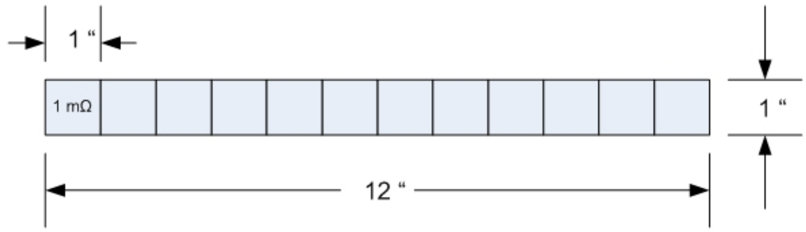

Figure 2: A Rectangular Copper Trace

Next: What about Corners and Connectors?

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StuMichaels

Good article but short on a couple of details. How is the number of squares calculated for connectors soldered onto a board? Examples are given but not how the results were calculated. Also, the statement is made that the resistivity of the plated copper is much higher than for pure copper; why? Don't some pcb fabricators start with thin copper and then plate up to 2,3 4 or higher oz thicknesses? If so, shouldn't the resistivity be modified for this case?

Jun 30, 2013 4:36 PM EDT

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BCBaker

This is an excellent article. This technique applies across various trace lenghts and widths. With a company I use to work for, we used this technic to determine the resistance of a Nicrone pad.

Apr 25, 2013 7:09 PM EDT

0 | 0

Reply

Thinking_J

Units?.. .doesn't matter.
Use the same technique when designing embedded resistors or designing thick/thin film resistors... The resistive material is specified in "ohms per square" .. 1 ohm/sq, 10k ohm/sq., what ever. The only remaining issue is wattage... or total area and it's thermal characteristics.

1"x 1" or .01mm x .01mm, you don't care , resistance is equal , only the wattage is different.

Apr 18, 2013 7:44 PM EDT

0 | 0

Reply

gabex

I like the principle, but I don't really understand why imperial units are used. I'm probably too sensitive about this, sorry, cause I like the content of the article. Nowadays metric is used in product design, since dimensions expressed in proper binary imperial (7/128") would be a difficulty to most mechanical engineers. The newest SMD packages are also using metric (SSOP: e=0.65/0.5 instead of SOIC: e = 50mil), so I hope the engineer community will solve this in the short future.

Apr 15, 2013 5:32 AM EDT

0 | 0

Reply

Backwoods Engineer

If you want metric, why not just convert the units and use the same technique? Do you want the author to do all the work for you?

It's an excellent article, and a clever graphical technique for simplifying a problem that occurs regularly in power electronics.

Apr 18, 2013 1:01 PM EDT

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Reply

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antokdavis

The method is to calculate DC resistance rite? In power electronics, if you have switching current, the ac resistance at that frequency is required. So how to extend this into calculating AC resistance???

Jan 7, 2014 11:17 PM EST

Reply

Ash_ee

I think either I'm missing something here, or you are. But consider this very important statement by the author in the text:

"Hence, the resistance of the copper is independent of the square's size that we measure. It just depends upon the resistivity of the material and the thickness."

It doesn't matter whether you measure traces and copper areas in metric or imperial, the unit does not come into it, only the shape.

Apr 18, 2013 1:21 PM EDT

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