EDN NETWORK

[Sheet inductance of a cavity: Rule of Thumb #16]

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Spoiler summary: The sheet inductance of a square cavity is 32pH per mil of dielectric spacing.

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

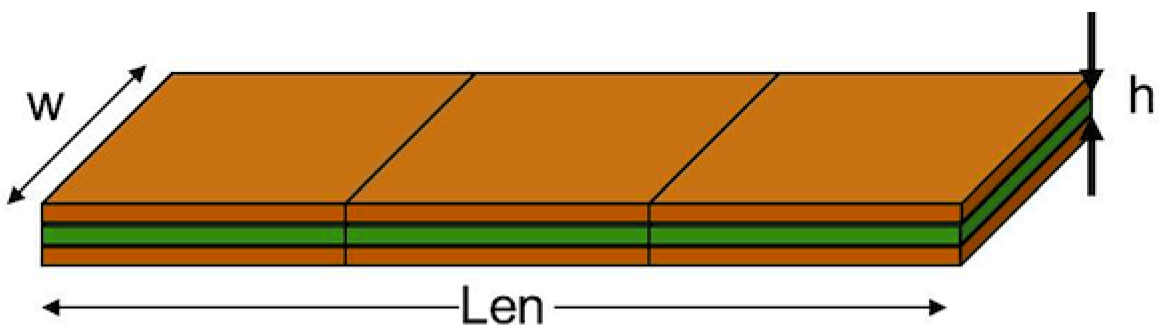
Previous: Rule of Thumb #15: The loop inductance of a circular loop

In this rule of thumb, we continue the inductance theme from the last rule of thumb. An important element of all power distribution networks is the cavity composed of adjacent power and ground planes.

We can estimate the loop inductance of a rectangular section cut from the cavity, using the same analysis we did when we looked at the trace resistance, leveraging the sheet resistance and number of squares.

In the special case of two long, wide, traces on top of each other, with a thin dielectric between them as illustrated below, the loop inductance down one trace and back on the other, can be estimated as:

$$L_{loop} = \mu_0 \times h \times \frac{Len}{w} = 32\frac{pH}{mil} \times h \times \frac{Len}{w}$$



This assumes the current flow is uniform from the left edge of one trace, down the long length, connecting to the other trace at the right end, and flowing back on the other trace to its left edge.

In this case, the loop inductance of this complete path can be well approximated with a simple relationship. It also points out how each of the three geometry terms relate to loop inductance; they are the most important design principles of how to engineer interconnects for lower loop inductance.

1. The shorter the length of the path, the lower the loop inductance.
2. The wider the trace, the more the current can spread out in its path, and the lower the loop inductance.
3. The closer the outgoing and incoming currents can be brought together (the thinner the dielectric between them), the lower the loop inductance.

In this special geometry, where the thickness is very small compared to the width, these terms scale linearly.

In the special case of a section of the two planes in the shape of a square, where the length equals the width, the loop inductance is just 32pH/mil × h. If we double the length of a side of these traces, the loop inductance doubles. But, if we also double the width of the pair of traces, maintaining the shape of a square, the loop inductance is halved. These two trends cancel out and the loop inductance stays the same.

This is a remarkable and useful observation. *Any* section of a cavity, cut out in the shape of a square, will have the same loop inductance, independent of the size of the square. This assumes the current flows uniformly into one edge and back out the adjacent plane's edge. We call this loop inductance, loop inductance per square, or the sheet inductance of the cavity.

For example, if the dielectric spacing is 10 mils – a common layer thickness – the loop inductance per square is 32pH/mil × 10 mil = 320pH per square. If a pair of traces is 2 inches long and 100 mils wide, there are 2"/0.100", or 20 squares, down the length, and each one has a loop inductance of 320pH. The total loop inductance of the pair of traces is 20 × 320pH = 6.4nH.

The most important figure of merit of a cavity used in a power distribution network is its sheet inductance. Most of the inductive properties of structures constructed from this cavity scale with the sheet inductance. This is why constructing a cavity with as thin a dielectric as possible between the power and ground places is so important. It has nothing to do with capacitance; it's all about loop inductance.

Now you try it:

1. The thinnest dielectric without a price premium is 2.8 mils. What is the sheet inductance of this cavity?
2. What is the loop inductance of a power/ground "plane" pair going from the power supply to the load if it is 4 inches long and 100 mils wide – if the cavity is 10 mils thick? If it's 2.8 mils thick? Is this a lot or a little?

Next rule of thumb #17: Quarter-wave stub resonant frequency.

Additional information on this and other signal integrity topics can be found at the Signal Integrity Academy, www.beTheSignal.com.